Section 1 - Introduction

As presented previously, the Quittapahilla Creek Watershed Association is particularly concerned about: channel instability caused indirectly by increased runoff from the urban centers and developing suburban areas, and the direct impacts associated with livestock grazing, the removal of riparian vegetation, and channel modifications; degraded water quality associated with sediment and nutrient loadings from upland sources (e.g., cultivated areas, parking lots, streets, highways, and rooftops) and point source discharges; and impacts to in-stream habitat resulting from sediment and nutrient loadings, and channel modifications implemented by private landowners.

A number of private organizations and public agencies have been working with the Quittapahilla Creek Watershed Association to improve the water quality and aquatic habitat of Quittapahilla Creek. However, there has been no comprehensive assessment, nor coordinated effort to identify and prioritize water quality, habitat and stream channel stability problems throughout the watershed. As a consequence, targeting of stream reaches for improvements has been on a project-by-project basis. There is no Master Plan or Action Strategy for the Quittapahilla Creek Watershed that serves to focus funding and restoration and management efforts where they are most needed.

The Quittapahilla Creek Watershed Association believes that their best chance for resolving the existing problems and avoiding future problems is to step back from the current project-based approach and develop a comprehensive plan of action based on an assessment of the entire watershed.

The Watershed Association's goals and objectives for the Quittapahilla Creek Watershed Project are presented below:

1. Establish benchmarks for evaluating and documenting changes in the watershed by assessing current hydrologic, water quality, in-stream habitat, and channel stability conditions.

2. Identify and prioritize restoration and management strategies to address existing hydrologic, water quality, in-stream habitat, and channel stability problems.

3. Determine the potential for future hydrologic, water quality, in-stream habitat, and channel stability problems.

4. Develop recommendations for management and protection strategies that will prevent and/or minimize future problems.

The restoration and management strategies outlined in this volume of the report were developed to achieve these overall project objectives. The first sections of this volume focus on strategies designed to address existing hydrologic, water quality, in-stream habitat, and channel stability problems. They include best management practices for controlling runoff from agricultural land, best management practices for controlling runoff from urban land and channel stabilization measures focused on restoring and stabilizing stream reaches impacted by livestock grazing, urban runoff and channel alterations along Quittapahilla Creek and its tributaries. The final section of this volume provides recommendations for agricultural programs and development policies and regulations intended to prevent and/or minimize future problems.

Section 2 – Methods for Identifying and Prioritizing Restoration and Management Strategies

A comprehensive analysis was conducted to identify and prioritize potential best management practices and restoration projects in the subwatersheds and along the main stem of Quittapahilla Creek. The analysis was based on an evaluation of the data collected during the assessment phase of the project. The comprehensive analysis process included:

2.1. Identification of Potential Watershed and Stream Management and Restoration Projects.

Potential projects were identified from a list of subwatershed and main stem problem sites identified in Volume 1 of this report. These projects were selected for their potential for reducing loadings of sediment and other pollutants, correcting channel instability, and improving in-stream habitat problems and include two major types of measures.

- Source-Based Measures

Source-Based Measures are focused on upland problem areas and include implementation of agricultural best management practices such as crop rotation, cover crops, conservation tillage and residue management, strip cropping/contour farming, terraces and diversions, nutrient management, grazing land management; installation of quality and quantity management facilities for controlling urban storm water runoff, construction of wetlands in floodplain areas to increase valley storage, reduce the erosive effects of flood waters, and create wildlife habitat.

- Stream-Based Measures

Stream-Based Measures are focused on stream channel problems and include installation of stream bank fencing and livestock crossings to limit the impacts associated with livestock grazing, modifications to golf course maintenance practices to reduce impacts to riparian vegetation, modifications to bridges and culverts to reduce effects on flood conveyance and sediment transport capacity, removal of fish barriers, restoration of stable channel form, and stream bed and bank stabilization utilizing grade control and flow diversion structures and native materials.

2.2 An Evaluation of the Effectiveness of Implementing Restoration and Management Projects

Implementation of restoration and management measures designed to correct the problems in the Quittapahilla Creek watershed will require the expenditure of a considerable amount of public funds and resources. Prior to committing these funds and resources, public officials will want to know whether the effort will ultimately achieve the stated objectives of improved water quality, channel stability, and restored habitat.

Therefore, an evaluation was conducted to determine the effectiveness of implementing the recommended restoration and management measures. The measures were grouped into three major categories, each denoting the water quality problems they are intended to correct. The categories include agricultural best management practices, urban best management practices, and channel stabilization measures. Although other benefits are expected to be derived from implementing the various measures (e.g., reduced peak flows, improved habitat, etc.) the evaluation focused on determining the effectiveness of measures in reducing sediment and nutrient loadings. This required that category specific evaluation methods be developed. The evaluation methods used to evaluate each category are described below.

2.3 Prioritization of Management and Restoration Projects

Given the number and type of problems identified in the watershed, it was considered critical that some guidance be provided to focus available funding and resources where they will provide the most benefit relative to the overall project objectives and where they have the greatest potential for success. Therefore, the intent of this phase of the evaluation process was to prioritize the restoration and management measures based on their potential for correcting channel stability, water quality, and in-stream habitat problems along Quittapahilla Creek and its tributaries.

Section 3 - Potential Best Management Practices

3.1 General Approach

Broadly speaking, Best Management Practices BMP's can be either structural or non-structural approaches used to reduce pollutant loads in watersheds draining both urban and rural areas. While there is no universally accepted definition of BMPs, the Soil and Water Conservation Society (SWCS) defines a BMP as "a practice or combination of practices that are determined by a state or designated area-wide planning agency to be the most effective and practicable (including technological, economic, and institutional considerations) means of controlling point and non-point source pollutants at levels compatible with environmental quality goals." Alternatively, Novotny and Olem (1994) state that, "BMPs are methods and practices for preventing or reducing non-point source pollution to a level compatible with water quality goals." When referring to rural areas, such BMPs are often called *conservation practices* or *agricultural* and *silvicultural* BMPs.

When considering options for BMP implementation, it is often useful to know how effective such BMPs might be in terms of reducing various types of pollutants such as sediment, nitrogen, and phosphorus. There is a very wide range of BMPs that could potentially be employed, as well as a wide range of associated costs and inherent pollutant reduction efficiencies. At the farm scale, it is critical that the most cost-effective BMP be implemented to address the pollutant(s) of concern at specific geographic locations given the marginal economies of this industry. Conversely, when addressing general water quality concerns within a watershed, it is not as important to identify specific BMPs for implementation at exact locations (at least at the planning stage). However, it is very useful to have a good sense of whether or not general types of BMPs would be potentially beneficial in reducing pollutant loads within a watershed in which non-point source pollutants are of primary concern.

3.2 Best Management Practices for Controlling Agricultural Runoff

3.21. Evaluation Methods

As described in the Findings Report, the Generalized Watershed Loading Function (GWLF) model with a GIS software (ArcView) interface (AVGWLF) developed by Pennsylvania State University was utilized to analyze water quality during the assessment phase of this study. The analysis focused on identifying general areas where pollutant loadings indicate that best management practices should be implemented.

A companion tool that runs within *AVGWLF* was used in this phase of the study to evaluate the potential benefits of using various best management practices (BMPs) within the Quittapahilla watershed. This tool, called *PRedICT* (The Pollution Reduction Impact Comparison Tool), allows the user to create various "scenarios" in which current landscape conditions and pollutant loads (both point and non-point) can be compared against "future" conditions that reflect the use of different pollution reduction strategies such as agricultural and urban best management practices (BMPs), stream protection activities, the conversion of septic systems to centralized wastewater treatment, and upgrading of treatment plants from primary to secondary to tertiary.

The tool includes pollutant reduction coefficients for nitrogen, phosphorus and sediment, and also has built-in cost information for an assortment of pollution mitigation techniques. A rather simple cost-accounting approach is used to estimate load reductions and their associated costs. The user initially specifies desired conditions such as the number of acres of agricultural BMPs to be used, the number of septic systems to be converted to centralized wastewater treatment, miles of riparian buffers, percentage of urban areas to be treated by wetlands and detention basins, etc. Based on this information, built-in reduction coefficients and unit costs are utilized to calculate resultant nutrient and sediment load reductions and scenario costs.

While information for *PRedICT* can be compiled manually, the most efficient way to derive input data is to use the *AVGWLF* watershed modeling tool as was done in this study. Among others things, *AVGWLF* automatically creates a "scenario" file that can be used as input to *PRedICT*. This input file contains information on watershed conditions and pollutant loads that can serve as the "initial" conditions from which future scenarios can be developed. While information on nutrient and sediment loads, as well as the presence of existing BMPs, can be developed and brought in via the use of *AVGWLF*, full editing capabilities are provided within *PRedICT* to allow for revised data input based on the user's local knowledge of the watershed being considered.

PRedICT was primarily developed using Visual Basic programming software. It is comprised of the following basic components:

- **a.** Input Screens. These screens (Visual Basic forms) are used to specify data sets and parameter values used in subsequent load and cost calculations.
- **b.** Scenario Files. These text files with ".scn" extensions are used to import data from an *AVGWLF* model run (if they exist) and to store output from *PRedICT* model runs.
- **c.** Load and Cost Algorithms. These compiled Visual Basic routines are imbedded in *PRedICT*, and are used to make the load reduction and cost calculations.

Although options exist for the analysis of various pollution mitigation strategies in *PRedICT*, for the purposes of this study only selected agricultural BMPs were evaluated using this methodology. Other mitigation strategies such as urban BMPs and stream stabilization activities were evaluated using other methods.

3.2.2 Agricultural BMP Options in *PRedICT*

Within *PRedICT*, BMP systems rather than individual BMPs are more often used as the basis for agricultural load reductions. This is because, as recognized by the Chesapeake Bay Program, BMPs are typically used in combination rather than individually to mitigate on-farm loss of soil and nutrients. Following this usage, the Pennsylvania Department of Environmental Protection has developed a guidance document that describes the different BMP systems that are recognized and eligible for funding through the State Conservation Commission (PaDEP, 2000) to mitigate water quality problems in agricultural areas. While not necessarily identical, the BMP systems used in *PRedICT* are based on the more generic and widely-used BMPs described in the latter document. Moreover, in the current version of *PRedICT*, BMP usage and descriptions were revised to more closely follow comparable mitigation strategies used within the Chesapeake Bay Model (USEPA, 1995). The agricultural BMP options used in the current version of *PRedICT* are given in Table 3.1.

3.2.3 Pollutant Reduction Efficiencies

While hundreds of studies have been completed over the past 25 years on the efficiencies of BMPs for reducing various pollutants (primarily sediment and nutrients), most of these studies have focused on the more frequently-used BMPs. Additionally, standard terminology and procedures in describing the BMPs and the reductions achieved have not been uniformly applied.

Within *PRedICT*, information on pollutant reduction efficiencies have been drawn primarily from four different sources, including Dillaha, Yagow and Pease (2000), Ritter and Shirmohammadi (2001), Susquehanna River Basin Commission (1998), and U.S. EPA (1990). The first and fourth documents are exhaustive literature reviews of the results of hundreds of BMP efficiency studies conducted across the country over the last 25 years. In both documents, synopses of reduction efficiencies are reported for about two dozen BMPs, which sometimes overlap in terms of terminology and procedures, and sometimes do not. The Susquehanna River Basin Commission document reports the results of a study evaluating pollutant mitigation strategies in the Susquehanna River Basin and the associated potential nutrient reduction. The results are based on the use of non-point source-related reduction efficiency values utilized in the EPA's Chesapeake Bay watershed model (U.S. EPA, 1995). Finally, Ritter and Shirmohammadi (2001) is a recently released textbook that, among other things, presents the results of a number of recent BMP studies completed by various researchers around the country.

Description	Option	Comments
Cropland Protection	BMP 1	Crop rotation, cover crops
Conservation Tillage	BMP 2	Cultivation with minimal soil disturbance
Strip Cropping/Contour Farming	BMP 3	
Agricultural Land to Forest Conversion	BMP 4	
Agricultural Land to Wetland Conversion	BMP 5	
Nutrient Management	BMP 6	
Grazing Land Management	BMP 7	Rotational grazing with fenced areas
Terraces and Diversions	BMP 8	

Table 3.1 - Agricultural BMP options used in *PRedICT*

Composite pollutant reduction values for the generic BMP options used in *PRedICT* are presented in Table 3.2. These values essentially reflect the average values for the individual BMPs that comprise each BMP option. As can be seen in the table, efficiency values are provided for nitrogen, phosphorus, and sediment. Due to the nature of the studies used in deriving the individual BMP values (i.e., they were primarily "runoff plot" studies), the efficiency values shown are only used to estimate reductions in surface runoff loads. This is very important with respect to evaluating reductions in nitrogen loads since, at the watershed level, much of the non-point source load can be contributed via the sub-surface movement of nitrates in agricultural areas. In addition to surface runoff-based load reductions, adjustments to loads are also made within *PRedICT* to groundwater contributions based on the particular BMP option utilized.

3.2.4 Implementation Costs

As with the reduction efficiency values, the costs associated with implementing the various individual BMPs were drawn from several sources. The primary one used, however, was the Conservation Catalog prepared by the Pennsylvania Conservation Partnership (2000). In addition to a description of various agricultural conservation practices currently used in Pennsylvania, the publication also has average costs for these practices at the time the document was written. Another useful document was a BMP guidance document prepared earlier by the U.S. EPA (1990).

Within *PRedICT*, only the costs associated with initial BMP implementation and construction are considered; long-term operational and maintenance costs are not included. These costs are shown in Table 3.3. In calculating the cost for any given BMP system, the separate costs for each individual BMP are calculated and subsequently summed according to the set of individual BMPs comprising each system.

BMP SYSTEM/TYPE	Nitrogen	Phosphorus	Sediment
BMP 1	25	36	35
BMP 2	50	38	64
BMP 3	23	40	41
BMP 4	95	94	92
BMP 5	97	92	98
BMP 6	70	28	-
BMP 7	43	34	13
BMP 8	44	42	71

Table 3.2 - Estimated BMP reduction efficiencies (%) by pollutant type. Notes on Table Usage:

- Values represent estimated reductions in surface runoff-associated loads only.
- Values represent percent reductions. For example, 36% of the surface P load can be reduced by implementing BMP 1.
- No value is reported for sediment for BMP 6 since this BMP (nutrient management) is typically not used for sediment reduction.
- The reduction values given for BMP 6 assume a “balanced” approach to reducing N and P loads. Otherwise, a value of 75 is recommended if the reduction of either pollutant is addressed at the expense of the other in the nutrient management plan. It is rare that a value of 75 would be used to reduce both nutrients at the same time.

BMP Type	Cost
Conservation Tillage	$30 per acre
Cover Crops	$20 per acre
Grazing Land Management	$360 per acre
Contour Farming / Strip Cropping	$10 per acre
Vegetated Buffer Strips	$1,500 per mile
Terraces and Diversions	$500 per acre
Nutrient Management	$110 per acre
Crop Rotation	$30 per acre
Agricultural Land Retirement	$5,000 per acre

Table 3.3 - Costs by Best Management Practice type.

3.2.5 Potential BMP Implementation within the Quittapahilla Watershed

In estimating the potential load reduction benefits of various mitigation strategies within the Quittapahilla watershed, the intent was to estimate the maximum reductions in sediment and nutrient loads that might be obtained by implementing agricultural BMPs. To simplify the BMP evaluation process, scenarios in which a combination of conservation tillage, nutrient management, and grazing land management was used in each of the sub-watersheds were developed. Other potential combinations are, of course, possible. However, it was not the intent of this exercise to find the optimum BMP scenario within each sub-watershed; rather, it was to provide a sense of the magnitude of possible reductions that might be possible solely via the implementation of agricultural BMPs.

As described in the Findings Report, a number of mitigation measures have already been implemented in various sub-watersheds of the Quittapahilla Creek watershed. In these cases, simulations were performed under the assumption that BMPs will be implemented in the remaining "untreated" agricultural areas. In the other sub-watersheds, simulations were done under the assumption of "full" BMP implementation in agricultural areas.

The results of the BMP scenario evaluations made using *PRedICT* are shown in Table 3.4. As can be seen from this table, total reductions of 45%, 64%, and 57% were estimated for nitrogen, phosphorus, and sediment, respectively, if BMPs were implemented in the remaining agricultural areas. These reductions, of course, are only estimates since actual reductions would depend on the actual suite of BMPs implemented, how well they were installed, and the degree to which they are maintained after installation. However, it does provide some insight into the types of load reductions that might be possible with this type of mitigation measure.

Table 3.4 – Nutrient and sediment load reductions based on potential agricultural BMP implementation.

Shed No.	Area (ac)	N (current)	N (max BMPs)	N Reduction	% N Red	P (current)	P (max BMPs)	P Reduction	% P red	S (current)	S (max BMPs)	S Reduction	% S red	Cost
1	2495	23333	19217	4117	0.18	900	437	463	0.51	843413	385458	457954	0.54	$369,635
2	857	12458	10081	2377	0.19	452	135	318	0.70	465255	134287	330968	0.71	$145,042
3	4419	235776	61691	174085	0.74	6787	1360	5427	0.80	3143889	1363819	1780070	0.57	$670,024
4	2628	49233	42713	6520	0.13	1292	591	701	0.54	1274490	460479	814011	0.64	$498,860
5	1635	39066	30570	8496	0.22	1100	397	703	0.64	1187613	246060	941553	0.79	$347,631
6	968	41064	6478	34585	0.84	481	123	357	0.74	332735	162504	170230	0.51	$99,017
7	529	5746	4304	1442	0.25	223	84	139	0.62	211680	51507	160173	0.76	$87,731
8	1109	20167	16202	3965	0.20	556	216	340	0.61	629087	143927	485160	0.77	$206,568
9	299	820	558	262	0.32	62	33	29	0.46	85995	23424	62571	0.73	$6,032
10	598	4106	3409	697	0.17	143	73	71	0.49	187866	53698	134168	0.71	$33,896
11	2285	45994	42210	3784	0.08	981	587	395	0.40	744188	457641	286546	0.39	$468,590
12	3767	57204	49090	8114	0.14	1762	811	950	0.54	1844483	827936	1016547	0.55	$584,381
13	4298	102515	93576	8939	0.09	1960	1200	761	0.39	1122786	708874	413912	0.37	$911,830
14	4080	275733	49943	225790	0.82	6681	836	5845	0.87	1613840	799235	814604	0.50	$547,810
15	2213	40431	12979	27452	0.68	750	291	459	0.61	592263	374114	218149	0.37	$242,703
16	7291	120660	106067	14593	0.12	3925	2516	1409	0.36	3293829	1607178	1686651	0.51	$915,585
17	2225	33381	28537	4844	0.15	878	390	487	0.56	714641	205621	509020	0.71	$303,281
18	2650	42243	35560	6683	0.16	1067	478	589	0.55	1113084	337771	775313	0.70	$421,059
19	906	4284	3914	370	0.09	146	106	40	0.27	91287	48144	43143	0.47	$60,467
20	2302	9704	8586	1118	0.12	476	329	148	0.31	466358	256109	210249	0.45	$62,104
21	1526	37143	33364	3779	0.10	829	362	467	0.56	841869	218762	623107	0.74	$256,376
Totals	49081	1201064	659050	542013	0.45	31450	11354	20096	0.64	20800647	8866548	11934099	0.57	$7,238,622

Notes:

"Shed No." = sub-watershed number, "ac" = acres, "N" = nitrogen, "P" = phosphorus, "S" = sediment, "current" = existing load, "max BMPs" = load based on maximum agricultural BMP implementation

All loads are in pounds per year

3.2.6 Prioritization of Agricultural Best Management Practices

As Table 3.2 shows the agricultural BMPs that have the most significant effect on reducing nutrient and sediment loadings involve conversion of marginal crop and pasture land to forest and/or wetlands. These marginal areas include land with steep slopes with highly erodible soils, and very wet or very droughty soils. These types of conditions generally provide poor productivity and should be given strong consideration for conversion. The other BMPs that have a significant effect on reducing nutrient and sediment loadings include conservation tillage and the use of terraces and diversions for cultivated land.

Table 3.4 indicates that the subwatersheds that would achieve the greatest reduction in nutrient loadings by implementing all of the above practices include Subwatersheds 6 – Upper Killinger Creek; 14 – Lower Snitz Creek; 3 – Confluence of Main Stem Quittaphilla Creek and Killinger Creek; and 15 – Brandywine Creek with reductions in nitrogen and phosphorus loadings of 84% and 74%, 82% and 87%, 74% and 80%, and 68% and 61%, respectively.

Table 3.4 indicates that the subwatersheds that would achieve the greatest reduction in sediment loadings by implementing all of the above practices include Subwatersheds 5 – Upper Killinger Creek and Gingrich Run; 8 – Middle Gingrich Run; 7 – Buckholder Run; 21 – East Fork Tributary of Snitz Creek; 9 – Tributary of Gingrich Run; 2 – Lower Main Stem Quittapahilla Creek; 10 – Upper Gingrich Run; 17 – Upper Quittapahilla Creek; 18 – Upper Bachman Run; and 4 – Middle Killinger Creek with reductions in sediment loadings of 79%, 77%, 76%, 74%, 73%, 71%, 71%, 71%, 70%, and 64%, respectively.

It is strongly recommended that NRCS and the Conservation District work closely with the agricultural landowners in these subwatersheds to implement these agricultural practices where they are applicable.

3.3 Best Management Practices for Controlling Urban Runoff

Urban stream restoration is arguably the most difficult of all watershed objectives to attain. The broad objective of this plan is to restore the functional integrity of the Quittapahilla Creek ecosystem, as demonstrated by the reestablishment and persistence of important aquatic species or ecosystem functions that had been diminished over time by urbanization. It is a complex and costly process of repair that involves stormwater retrofits, riparian reforestation, stream restoration, wetland restoration and creation, and removal of fish barriers. The ability to meet this target in the urbanized subwatersheds will be governed by two factors. First, enough opportunities must be available to retrofit BMP systems into the urban subwatersheds to provide meaningful hydrologic control and pollutant removal. Second, any new watershed development that occurs must be accompanied by stringent BMP systems so that the improvements brought about by retrofits are not cancelled out.

3.3.1 – Regional Approach versus On-Site Management Practices

In developing an Urban Stormwater Control Plan for the Quittapahilla Creek watershed, consideration was given to a regional approach versus on-site management practices. Significant advantages were identified relative to regional on-stream facilities in comparison to smaller on-site management practices. One significant advantage of regional facilities is that, when dealing with non-point source pollutant sources, this approach is better able to capture and treat pollutants that are generated from often-times non-discrete sources. These regional facilities capture and treat the aggregate runoff from larger subwatershed areas without the need to identify specific pollutant sources. In comparison, site-specific BMP's, assuming they could even be effective at capturing non-point pollutant sources, would require substantial additional watershed assessment and investigation to inventory pollutant sources and localized topographic drainage patterns well outside the immediate stream corridor.

Additionally, regional BMP's provide the flexibility to locate facilities where open space exists. It should be noted that the BMP's recommended in this study are intended to address existing stormwater runoff conditions. Runoff from future development should be controlled with management strategies required as part of the land development review process. This means that areas contributing to the problems have already been developed and may no longer have open space areas available for BMP construction. In this situation, many cases would literally be untreatable using an on-site approach.

The regional facilities also have an advantage in terms of generally involving fewer total number of individual land owners throughout the watershed. Though the land area required at each regional facility location is larger than an individual site-specific BMP site, the number of site-specific locations required to achieve the same level of treatment is greatly increased, thus increasing the number of involved individual land owners. In several cases, the regional BMP sites identified in this study are even located on publicly owned land, further simplifying the process to obtain land owner consent.

One final generalized comparison relates to project funding. For regional facilities, their benefits are more easily understood and recognized as having broader application to a larger number of people and a larger area than a site-specific, more localized BMP. Consequently, funding for regional facilities can often times be more easily justified.

3.3.2 – Evaluating BMP Options

Best Management Practices (BMPs) for controlling urban runoff include a wide range of structures and treatment options that can be used to convey storm water runoff, reduce the hydrological impacts due to increased quantity of storm water runoff, and reduce the pollutant loadings delivered by storm water runoff. As shown in Table 3.5 below, stormwater BMPs can include: bioretention, grassed filter strips, grassed swales, infiltration trenches and basins, riparian buffers, sand and organic filters, stormwater wetlands, water quality inlets, and retention or extended detention wet ponds.

Best Management Practice	Cost	Maintenance	Pollutant Removal (%)				
			TSS	Phosphorus	Nitrogen	Metals	Bacteria
Bioretention	Expensive	Intense Initially, Less over time	NA	65 – 85	49 – 92 *	43 – 97	NA
Grassed Filter Strip	Moderate – Low	Low	54 – 84**	25 – 40**	27 – 20**	16 – 55**	NA
Grassed Swale	Moderate – Low	Low	81	29	38	14 – 55	50
Infiltration Basin	Cost Effective	High to maintain effectiveness	75	60 – 70	55 – 60	85 – 90	90
Infiltration Trench	Somewhat Expensive	Very High, Moderate with pretreatment	75	60 - 70	55 – 60	85 – 90	90
Riparian Buffers	Low, increase property values	Low	63 – 89**	8 – 74**	17 – 99**	NA	NA
Sand and Organic Filters	Moderate – High	Very High, Moderate with pretreatment	66 – 98***	4 – 84***	44 – 47***	26 – 100***	55
Storm Water Wetland	Cost Effective	Moderate	71 – 83***	39 – 64***	19 – 56***	21 – 85**	78
Water Quality Inlets	Moderate – High	Very High	21	17	5	17 – 24	NA
Wet Pond	Cost Effective	Moderate	67	48	31	24 – 73	65

Table 3.5 Comparison of Post-Construction Best Management Practices (Source: USEPA, Office of Water Website)

Notes: NA – Not Available; * varies with chemical form; ** varies with filter/buffer width; *** varies with design components

Each BMP option considered has both unique capabilities and persistent limitations. These, in turn, were balanced with both the physical constraints imposed by natural features and historic land use and the overall management objectives for the watershed. In developing the BMP plan for Quittapahilla Creek watershed consideration was given to the following objectives and concerns:

- Reproduce Predevelopment Hydrologic Conditions

The historical concern in stormwater management has been to reduce the frequency and severity of downstream floods and stream channel erosion caused by runoff. In most areas, this goal is achieved by controlling the peak discharge computed for a specific design storm to predevelopment levels. BMPs designed to control small to intermediate storm events can be effective at reducing stream channel erosion.

- Provide Moderate Pollutant Removal Capability

In recent years, BMP designs have been developed to enhance pollutant removal during storms, and thereby improve the quality of stormwater runoff delivered to the receiving waters. BMPs differ markedly in the pollutant removal mechanisms they employ, and consequently, their performance in removing different pollutants can vary significantly. However, removal rates can be enhanced by increasing the volume of runoff effectively treated by the BMP, or by adding extra design features. Another important consideration in selecting the appropriate BMPs is which urban pollutants are to be targeted for removal in the watershed.

- Constraints

Many BMPs are constructed on sites for which they are not suitable. As a consequence, some BMPs experience chronic maintenance problems or nuisance conditions, and in extreme cases, may no longer function as designed. To prevent these sorts of problems from occurring, it is important to understand the physical restrictions associated with each type of BMP. In addition, field tests should be conducted to verify the physical conditions of a proposed BMP site.

- Cost-Effectiveness

The construction costs for different BMP options can vary substantially, even on similar sites. This is due to inherent differences in the methods and materials used for BMPs, as well as certain economies-of-scale. Since the cost of BMPs that are implemented by municipalities are eventually passed on to the public, cost-minimization should be a priority. This can be achieved by identifying the BMPs that meet your watershed restoration and management goals for the lowest initial cost and lowest long-term maintenance costs.

- Acceptable Future Maintenance Burden

BMPs can only continue to be effective if they are regularly inspected and maintained. Maintenance tasks for most BMPs include both low cost routine tasks and more expensive non-routine tasks, such as rehabilitation or sediment removal. Maintenance costs for BMPs can be significant. Over a twenty-year period they will often equal or exceed the initial construction cost. The cost and responsibility for maintenance is passed on to the public.

Consequently, it is critical to vest responsibility for maintenance: how and when tasks will be performed, how it is to be financed, and who will inspect the BMP. In most cases, the maintenance burden of a BMP is determined by the initial design and construction of the facility. If maintenance requirements are addressed during the design and construction phases, both the scope and cost of future maintenance activities can be sharply reduced.

- Neutral Impact on the Environment

Urban BMPs nearly always represent a significant modification to both the natural environment and the adjacent community. As such, BMPs can either enhance or degrade the amenity values that both provide. Comparatively small investments in design, landscaping, and maintenance can make a BMP an attractive feature of a community, or at least an unobtrusive one. Without such efforts, many BMPs appear unsightly or discordant, provide no habitat or recreational opportunities, and are plagued by nuisance problems. The importance of enhancing the amenity values of a BMP cannot be overemphasized, as community perceptions about a BMP are generally formed by the amenities they do or do not provide. These perceptions, in turn, strongly influence their acceptance of and support for these BMPs, which is critical if the community is expected to pay for maintenance.

3.3.3 – Developing the BMP Plan for Quittapahilla Creek

For this study, BMP's were analyzed based upon the ability to attenuate peak discharges while providing pollutant load removal for the lowest cost and lowest maintenance requirements over the life of the facility. The BMP that best obtains these goals is an extended wet detention pond.

When evaluating which areas of the Quittapahilla Creek watershed to target for implementation of urban best management practices, the subwatersheds draining the City of Lebanon ranked highest. Several factors lead to this determination: 1) the high percentage of impervious area in these subwatersheds; 2) the nature of urban runoff and its effects on stream channels; 3) the most intensely developed areas in these subwatersheds predate stormwater runoff control regulations and technology; 4) results of the water quality modeling, water quality monitoring, and sediment discharge study all indicate that the Upper Quittapahilla Creek and Brandywine subwatersheds are contributing a major portion of the sediment load to Quittapahilla Creek;. and 5) the U.S.

EPA's Phase II NPDES requirements mean that municipalities like the City of Lebanon are required to develop storm water management plans for controlling and treating urban runoff.

Twelve (12) sites were initially identified for implementation of storm water control best management practices (BMPs) during the field reconnaissance phase of the watershed assessment. Subsequent development of previously vacant parcels and other site constraints eliminated three of the original twelve sites. The nine (9) remaining BMP sites (shown on Plate 1) were conceptually designed using GIS topography with the goal of achieving maximum amount of attenuation volume based upon the physical characteristics of the sites. Elevation-Storage tables were constructed to analyze the storage capacity for each of the proposed BMPs. Existing sub-watersheds were analyzed with the USGS National Flood Frequency Program to obtain target peak discharges consistent with rural peak discharges for the one- and two-year storm events. Elevation-Discharge tables were then constructed from values obtained for the target peak discharges for the one- and two-year storm.

3.3.4 – Evaluation Methods

- Hydrologic Improvements

One major objective of the extended wet detention pond BMP implementation is the reduction of the bankfull discharge. Urbanization and development within the watershed over the past few decades has altered the infiltration/runoff characteristics of the watershed, and have led to higher peak flows at the 1-year to 2-year recurrence level. As previously mentioned, the bankfull discharge (usually falling between the 1- and 2-year discharges) is recognized as being the channel forming flow. The increases of the peak discharges within the Quittapahilla Creek system have led to increased rates of streambed and stream bank erosion, which takes a toll on downstream receiving waters. Therefore, in an effort to counteract the increases of the bankfull discharge from urbanization, the effect of placing extended wet detention ponds within various locales in the greater Lebanon area was studied to determine the magnitude of improvements that would be realized.

- Urbanized versus Pre-Urbanized Condition

To estimate the improvements which would be realized from the extended wet detention pond BMPs, three conditions must be modeled: pre-urbanization; unimproved post-urbanization; and, improved post-urbanization.

Soil mapping and land use mapping post-date the establishment of the City of Lebanon. Therefore, these parameters are unavailable for the estimation of pre-urbanization conditions with the HEC-HMS watershed model. To estimate the pre-urbanization conditions, the runoff curve number for three specific watersheds was lowered to simulate an undeveloped condition as summarized in Table 3.6.

SUBWATERSHED (HEC-HMS MODEL)	CALIBRATED CN (URBANIZED CONDITION)	CN USED FOR ESTIMATING THE PRE-URBANIZED CONDITION
Brandywine	74	64
Lebanon	81	64
Mid-Quitty	64	60

Table 3.6 - Runoff Curve Numbers developed for three specific watersheds to simulate undeveloped conditions

The HEC-HMS model was then run using the pre-urbanization parameters to establish a baseline for studying the effects of the proposed BMPs on the bankfull discharge. A graphical comparison of the calibrated urbanized and pre-urbanized hydrologic models is represented in Figure 3.1.

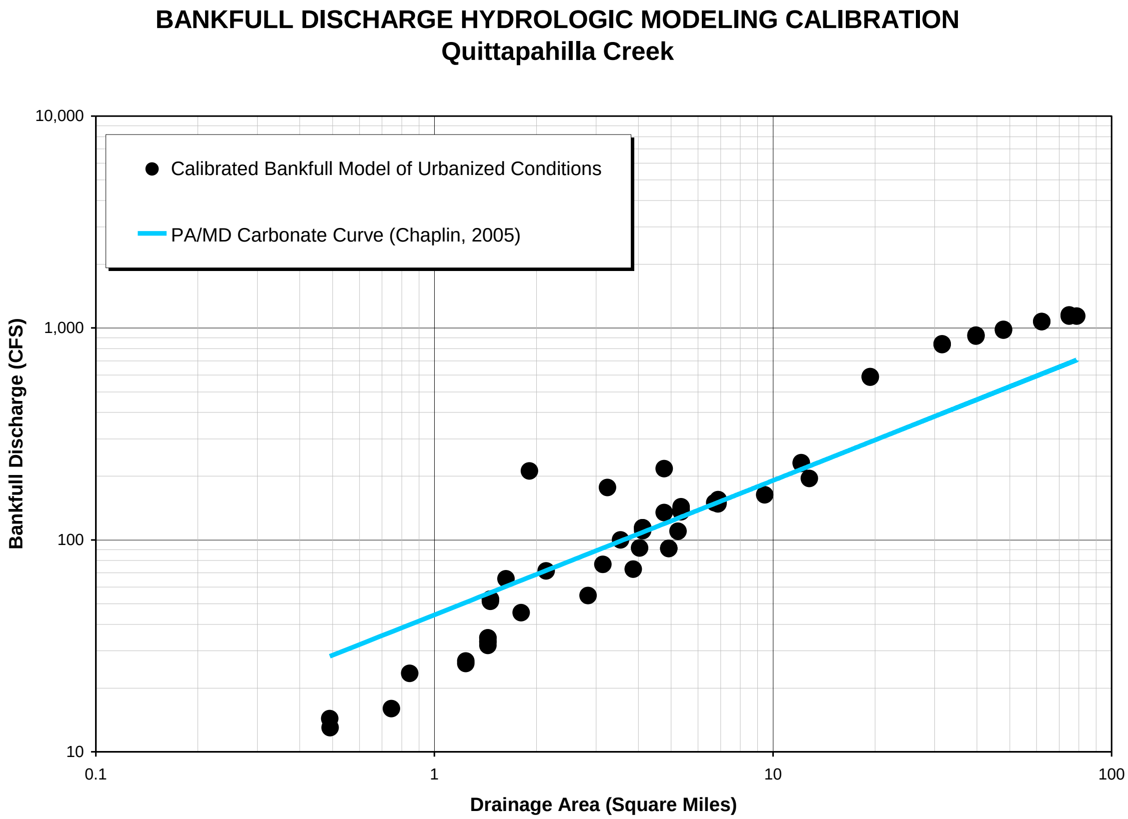


Figure 3.1 - Comparison of modeled bankfull discharges in the urbanized and pre-urbanized conditions. The model has been calibrated to the PA/MD carbonate geology regional curve.

- Impact of BMPs on the Bankfull Discharge

As noted, a major objective for implementing the extended wet detention pond BMPs within the greater Lebanon area is to counteract increases in the bankfull discharge that have resulted from urbanization. Ideally, the implementation of the BMPs would reduce the bankfull discharge down to pre-urbanization levels. As seen in Figure 3.2, the BMPs would be successful at reducing the bankfull discharges by approximately 20 to 30% along the main stem of Quittapahilla Creek.

- Verification of No Hydrograph Interference

In addition to analyzing the beneficial hydrologic impacts of the proposed BMPs on the bankfull discharge, the effects of the BMPs on the 100-year discharges was studied to verify that BMPs would not create hydrograph interference. All reaches and junctions within the HEC-HMS model were analyzed, and it was found the proposed improvements will not create any increases in the 100-year discharge within the Quittapahilla Creek watershed.

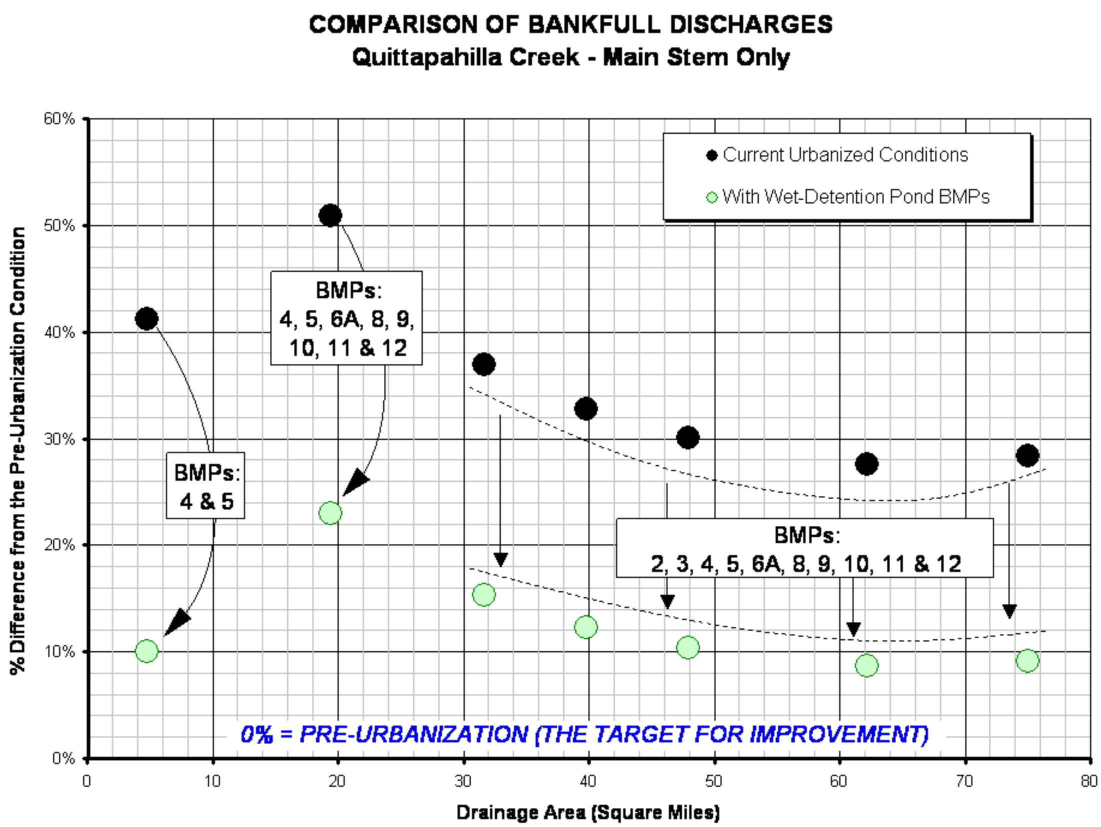


Figure 3.2 - Comparison of bankfull discharges following urbanization and reduced bankfull discharges following the installation of the proposed BMPs.

- Water Quality Improvements

A second major objective of implementing the proposed BMPs is to reduce the pollutant loading from the urbanized areas of the upper watershed. Creation of extended detention basins with a permanent pool will realize a water quality benefit. The standing volume of water within the wet pond will be displaced by the volume of storm runoff that enters the wet pond. This displaced volume of water will be clear of sediments and will have resided in the pond long enough to remove nitrogen and phosphorus (unlike the nitrogen, phosphorus and sediment laden waters that will enter the proposed BMPs).

- Method of Calculating Pollutant Load Reductions

Pollutant reduction potential of the proposed BMPs was analyzed in accordance with the methods outlined in Stormwater Best Management Practices (North Carolina Department of Environment and Natural Resources, April, 1999.). The estimation of the pollutant reduction potential of the BMPs is based upon the ratio of the permanent wet pool surface area (SA) to the uncontrolled upstream drainage area (DA). Optimally, an 85% reduction in sediment pollutant load is achieved when a certain SA/DA ratio is met for a specific wet pond depth. The SA/DA ratios and computed pollutant removal efficiencies for each of the proposed BMPs is listed in Table 3.7.

BMP	**SA/DA**	**ESTIMATED POLLUTANT REMOVAL EFFICIENCY**
2	0.06%	6%
3	0.03%	3%
4	0.08%	11%
5	0.47%	85%
6A	2.63%	85%
8	0.29%	17%
9	0.06%	8%
10	0.19%	27%
11	0.57%	51%
12	0.07%	17%

Table 3.7 – SA/DA Ratios and Pollutant Removal Efficiency for each proposed BMPs

- Pollutant Load Reductions

The pollutant removal efficiencies listed above are specific to each BMP and its direct watershed area. The combined effect of the pollutant removal properties of each BMP was analyzed to determine the level of nitrogen, phosphorus and sediment reduction that would be seen along the main stem of Quittapahilla Creek. These combined efficiencies are shown in Table 3.8.

BMPs	LOCATION	NITROGEN REDUCTION POTENTIAL	PHOSPHORUS REDUCTION POTENTIAL	SEDIMENT REDUCTION POTENTIAL
8, 9, 10 & 11	Subwatershed 15	16%	33%	38%
4, 6A & 12	Subwatershed 16	9%	18%	21%
5	Subwatershed 17	17%	34%	39%
3	Main Stem	1.3%	2.6%	3.0%
2	Main Stem	2.6%	5.2%	6.0%

Table 3.8 – Pollutant Removal Efficiency achieved by the combined effect of Proposed Urban Best Management Practices

3.3.5 – Proposed Urban Stormwater Best Management Practices

An extended detention stormwater wetland as shown in Figures 3.3, 3.4 and 3.5 was conceptually designed for each BMP site location to reduce peak discharges for the storm events that produce bankfull flows and reduce pollutant loading from the subwatersheds draining to these stream reaches. This section presents conceptual designs for the proposed BMPs, outlines the hydrologic and water quality benefits associated with the implementation of the BMPs, and provides preliminary cost estimates for design, permitting and construction of each BMP.

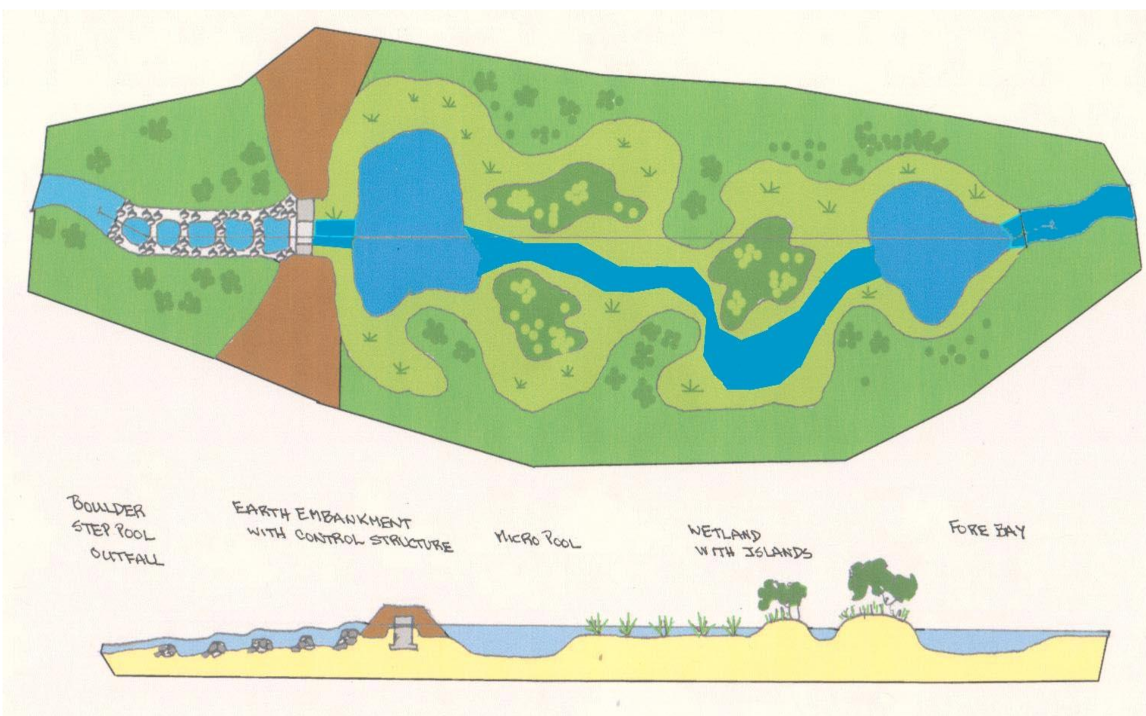


Figure 3.3 – Typical Stormwater Wetland in plan view (upper) and profile (lower)

A typical stormwater wetland design provides a 3-5ft deep permanent pool with additional temporary storage area above the permanent pool for attenuating stormwater runoff for storm events that produce bankfull flows.

Figure 3.4 – Stormwater wetlands in a residential subdivision

Figure 3.5 – Extended detention wet pond in a residential subdivision

BMP Site Location: 2

Sub-Watershed: 12

Total Drainage Area: 20.03 sq. mi.
Watershed Percent Impervious: 20%

SUB-BASIN

The contributing drainage area to BMP Site 2 is 20.03 square miles (12,820 acres). Site 2 is located on the main stem Quittapahilla Creek and collects runoff from Subwatersheds 15, 16, and 17. Although the headwaters of each of these subwatersheds are predominantly agriculture, there is a considerable land area that includes single family residential, multifamily residential, commercial, industrial, and institutional land uses.

SITE LOCATION

The site is located along the main stem Quittapahilla Creek immediately downstream of the concrete flume and upstream of the 22nd Street Bridge. It is bounded by the commercial properties along Route 422 to the north and Chestnut Street to the south. The site is currently forest that has been impacted by dirt bikes and ATVs. Quittapahilla Creek is very unstable along this reach.

DESIGN INFORMATION

Site 2 is a proposed 8.80 acre wet pond BMP with a 7.18 acre permanent pool at a maximum depth of 3 ft with a proposed storage volume of 14.68 acre-feet. The forebay would equal 10-15% of the total proposed water quality volume, or between 1.08 and 1.61 acre-feet. The control structure would be a single control outlet through an earthen berm and a larger spillway at the top of the berm for passage of more severe storm event flows. These structures will maintain an existing base flow and maximize the peak attenuation for the 1.5 year storm event. From the present urbanized conditions to the proposed installation of the wet detention pond BMPs, Site 2 will contribute toward reducing the bankfull discharge flows in the main stem of Quittapahilla Creek to within 10% of the pre-urbanized flow conditions. The Surface Area to Drainage Area Ratio (SA/DA) required for 85% pollution removal for this BMP is 0.97% (estimated for a 3' maximum depth permanent pool). However, the Surface Area to Drainage Area Ratio for BMP Site 2 is .00056, which indicates a removal efficiency of 6%. Design information is summarized in Table 3.8 and Figure 3.6 illustrates the design concept and site location for the proposed BMP.

Construction would also include the installation of buffer plantings, landscaping and slope stabilization. Property Owner/Parcel Information was not determined. However, the site may require the acquisition of private parcels and/or easements belonging to property owners who are not currently involved with this project. Construction cost estimate for this facility is detailed in Table 3.9.

Table 3.8 – Site 2 Proposed BMP Design Parameters Summary	
Design Parameter	**System Total**
Permanent Pool Surface Area, acre	7.18
Total Drainage Area, acre	12,820
Impervious Area, acre	2,564
SA/DA, percent	0.056%
Proposed Storage Volume, acre-ft	14.68
Control Structure	Stabilized Overflow Crest w/ Emergency Spillway
Pollutant Removal Efficiency, percent	6%
Estimated Cost, $	$359,250.00

Table 3.9 Site 2 Cost Estimate – Extended Detention Wet						
Item No.	**Description**		**Units**	**Quantity**	**Unit Price**	**Total Price**
	Engineering Phase Cost Estimate					
1	Base Survey with Topography and Property Delineations		LS	1.00	$5,000.00	$5,000.00
2	Engineering Design		LS	1.00	$25,000.00	$25,000.00
3	Permit Application and Securement		LS	1.00	$15,000.00	$15,000.00
4	Construction/ Permanent Easements and Associated Fees		LS	1.00	$15,000.00	$15,000.00
	Total of Engineering Costs:					$60,000.00
	Construction Phase Cost Estimate					
1	Mobilization/Demobilization		LS	1.00	$6,000.00	$6,000.00
2	Clearing and Grubbing		AC	8.80	$7,500.00	$66,000.00
3	Construction Survey and Stakeout		LS	1.00	$5,000.00	$5,000.00
4	Bulk Excavation		CY	12,000.00	$4.00	$48,000.00
5	Outlet Structure		LS	1.00	$5,000.00	$5,000.00
6	Rip-rap Erosion Protection		CY	300.00	$65.00	$19,500
7	Erosion and Sedimentation Control		LS	1.00	$6,000.00	$6,000.00
8	Fencing		LF	3,500.00	$2.00	$7,000.00
9	Access Gates		EA	2.00	$2,000.00	$4,000.00
10	Permanent Seeding and Mulching		AC	5.00	$3,000.00	$15,000.00
11	Tree, Shrub, and Aquatic Plantings		AC	2.00	$20,000.00	$40,000.00
12	Incidental Property/ Site Improvements		LS	1.00	$10,000.00	$10,000.00
13	As-Built Drawings		LS	1.00	$6,000.00	$6,000.00
	Sub-Total of Construction Costs:					$237,500.00
	Construction Costs Contingency				20%	$47,500.00
	Total of Construction Costs:					$285,000.00
	Operations and Maintenance Cost Estimate					
	Operations and Maintenance Cost Estimate as a Percentage of the Construction Costs				5%	$14,250.00
	TOTAL ESTIMATED PROJECT COST:					**$359,250.00**

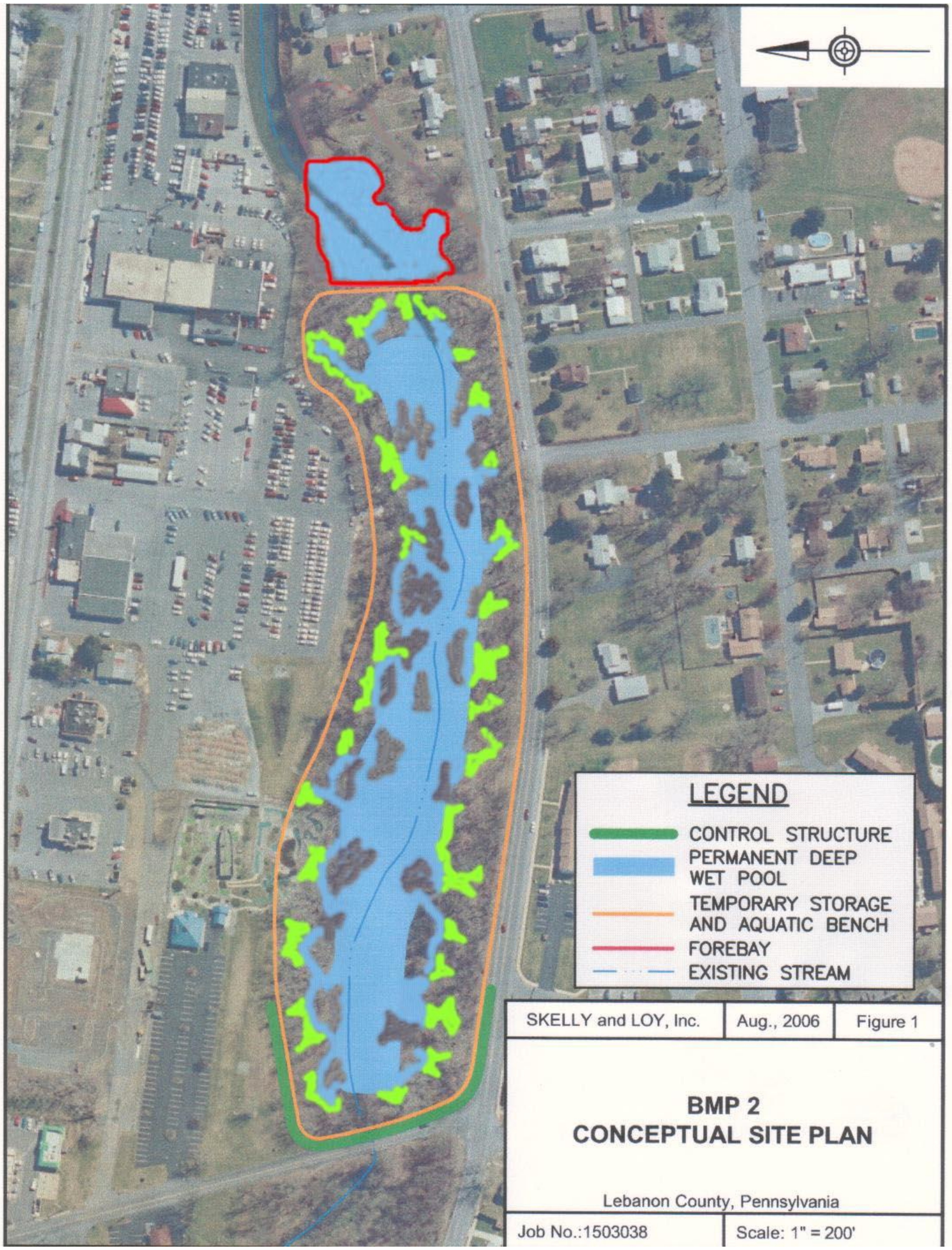


Figure 3.6 – Concept Design for BMP 2

BMP Site Location: 3

Sub-Watershed: 12

Total Drainage Area: 20.30 sq. mi.
Watershed Percent Impervious: 20%

SUB-BASIN

The contributing drainage area to BMP Site 3 is approximately 20.30 sq. mi. (12,993 acres). BMP Site 3 is located within the eastern portion of sub-watershed 12 of the Quittapahilla Creek watershed. The drainage area to this site includes the city of Lebanon and all headwater upstream drainage areas.

SITE LOCATION

The site is located along the main stem Quittapahilla Creek immediately downstream of Chestnut Street. It is bounded by agricultural properties to the south and residential and commercial properties along Route 422 to the north. The site is currently mowed floodplain with scattered trees. Quittapahilla Creek is unstable along this reach.

DESIGN INFORMATION

Site 3 is a proposed 5.59 acre wet pond BMP with a 4.23 acre permanent pool at a maximum depth of 3 ft with a proposed storage volume of 8.72 acre-feet. The forebay would equal 10-15% of the total proposed water quality volume, or between 0.63 and 0.95 acre-feet. The control structure would be a single control outlet through an earthen berm and a larger spillway at the top of the berm for passage of more severe storm event flows. These structures will maintain an existing base flow and maximize the peak attenuation for the 1.5 year storm event. From the present urbanized conditions to the proposed installation of the wet detention pond BMPs, Site 3 will contribute toward reducing the bankfull discharge flows in the main stem of Quittapahilla Creek to within 10% of the pre-urbanized flow conditions. The Surface Area to Drainage Area Ratio (SA/DA) required for 85% pollution removal for this BMP is 0.97% (estimated for a 3' maximum depth permanent pool). However, the Surface Area to Drainage Area Ratio for BMP Site 3 is .000326, which indicates a removal efficiency of 3%. Design information is summarized in Table 3.10 and Figure 3.7 illustrates the concept design and site location for the proposed BMP.

Construction would also include the installation of buffer plantings, landscaping and slope stabilization. Property Owner/Parcel Information was not determined. However, the site may require the acquisition of private parcels and/or easements belonging to property owners who are not currently involved with this project. Construction cost estimate for this facility is detailed in Table 3.11.

Table 3.10 – Site 3 Proposed BMP Design Parameters Summary	
Design Parameter	**System Total**
Permanent Pool Surface Area, acre	4.23
Total Drainage Area, acre	12,993
Impervious Area, acre	2,599
SA/DA, percent	0.0326%
Proposed Storage Volume, acre-ft	8.72
Control Structure	Stabilized Overflow Crest w/ Emergency Spillway
Pollutant Removal Efficiency, percent	3%
Estimated Cost, $	$299,314.00

Table 3.11 – Site 3 Cost Estimate – Extended Detention Wet					
Item No.	**Description**	**Units**	**Quantity**	**Unit Price**	**Total Price**
	Engineering Phase Cost Estimate				
1	Base Survey with Topography and Property Delineations	LS	1.00	$5,000.00	$5,000.00
2	Engineering Design	LS	1.00	$25,000.00	$25,000.00
3	Permit Application and Securement	LS	1.00	$15,000.00	$15,000.00
4	Construction/ Permanent Easements and Associated Fees	LS	1.00	$10,000.00	$10,000.00
	Total of Engineering Costs:				$55,000.00
	Construction Phase Cost Estimate				
1	Mobilization/Demobilization	LS	1.00	$6,000.00	$6,000.00
2	Clearing and Grubbing	AC	1.00	$7,500.00	$7,500.00
3	Construction Survey and Stakeout	LS	1.00	$5,000.00	$5,000.00
4	Bulk Excavation	CY	6,800.00	$4.00	$27,200.00
5	Outlet Structure	LS	1.00	$5,000.00	$5,000.00
6	Rip-rap Erosion Protection	CY	400.00	$65.00	$26,000.00
7	Erosion and Sedimentation Control	LS	1.00	$12,000.00	$12,000.00
8	Fencing	LF	2,100.00	$2.00	$4,200.00
9	Access Gates	EA	2.00	$2,000.00	$4,000.00
10	Permanent Seeding and Mulching	AC	7.00	$3,000.00	$21,000.00
11	Tree, Shrub, and Aquatic Plantings	AC	3.00	$20,000.00	$60,000.00
12	Incidental Property/ Site Improvements	LS	1.00	$10,000.00	$10,000.00
13	As-Built Drawings	LS	1.00	$6,000.00	$6,000.00
	Sub-Total of Construction Costs:				$193,900.00
	Construction Costs Contingency			20%	$38,780.00
	Total of Construction Costs:				$232,680.00
	Operations and Maintenance Cost Estimate				
	Operations and Maintenance Cost Estimate as a Percentage of the Construction Costs			5%	$11,634.00
	TOTAL ESTIMATED PROJECT COST:				**$299,314.00**

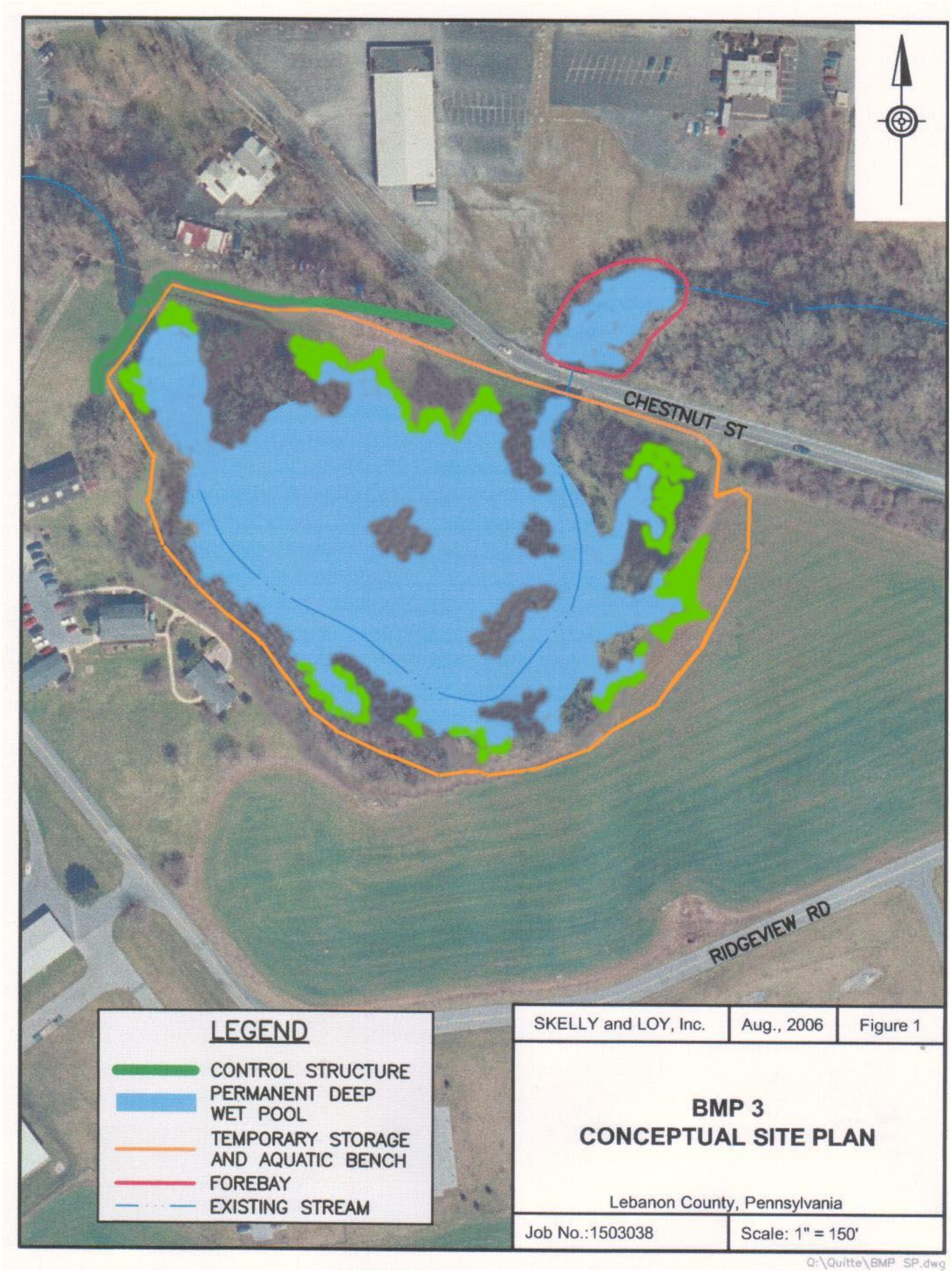


Figure 3.7 – Concept Design for BMP 3

BMP Site Location: 4

Sub-Watershed: 16

Total Drainage Area: 5.47 sq. mi.
Watershed Percent Impervious: 20%

SUB-BASIN

The contributing drainage area to BMP Site 4 is approximately 5.47 sq. mi. (3,498 acres). BMP Site 4 is located within the northern portion of sub-watershed 16 of the Quittapahilla Creek watershed. The drainage area to this site includes the city of Lebanon and all headwater upstream drainage areas.

SITE LOCATION

This site is located on the Main Stem Quittapahilla Creek immediately upstream of North Lincoln Avenue. It is bounded on the north by industrial property and on the south by a public parking lot and taxi operation. The site is floodplain with mowed grass on the industrial property and brush and weeds along the south side. The facility would encroach on the public parking lot.

DESIGN INFORMATION

Site 4 is a proposed 3.80 acre wet pond BMP with a 2.76 acre permanent pool at a maximum depth of 5 ft with a proposed storage volume of 5.82 acre-feet. The forebay would equal 10-15% of the total proposed water quality volume, or between 0.69 and 1.04 acre-feet. The control structure would be a single control outlet through an earthen berm and a larger spillway at the top of the berm for passage of more severe storm event flows. These structures will maintain an existing base flow and maximize the peak attenuation for the 1.5 year storm event. From the present urbanized conditions to the proposed installation of the wet detention pond BMPs, Site 4 will contribute toward reducing the bankfull discharge flows in the main stem of Quittapahilla Creek to within 10% of the pre-urbanized flow conditions. The Surface Area to Drainage Area Ratio (SA/DA) required for 85% pollution removal for this BMP is 0.70% (estimated for a 5' maximum depth permanent pool). However, the Surface Area to Drainage Area Ratio for BMP Site 4 is 0.000789, which indicates a removal efficiency of 11%. Design information is summarized in Table 3.12 and Figure 3.8 illustrates the concept design and site location for the proposed BMP.

Construction would also include the installation of buffer plantings, landscaping and slope stabilization. Property Owner/Parcel Information was not determined. However, the site may require the acquisition of private parcels and/or easements belonging to property owners who are not currently involved with this project. Construction cost estimate for this facility is detailed in Table 3.13.

Table 3.12 – Site 4 Proposed BMP Design Parameters Summary	
Design Parameter	**System Total**
Permanent Pool Surface Area, acre	2.76
Total Drainage Area, acre	3,498
Impervious Area, acre	700
SA/DA, percent	0.0789%
Proposed Storage Volume, acre-ft	5.82
Control Structure	Stabilized Overflow Crest w/ Emergency Spillway
Pollutant Removal Efficiency, percent	11%
Estimated Cost, $	$194,065.00

Table 3.13 – Site 4 Cost Estimate – Extended Detention Wet

Item No.	Description		Units	Quantity	Unit Price	Total Price
	Engineering Phase Cost Estimate					
1	Base Survey with Topography and Property Delineations		LS	1.00	$5,000.00	$5,000.00
2	Engineering Design		LS	1.00	$25,000.00	$25,000.00
3	Permit Application and Securement		LS	1.00	$12,000.00	$12,000.00
4	Construction/ Permanent Easements and Associated Fees		LS	1.00	$10,000.00	$10,000.00
	Total of Engineering Costs:					$52,000.00
	Construction Phase Cost Estimate					
1	Mobilization/Demobilization		LS	1.00	$6,000.00	$6,000.00
2	Clearing and Grubbing		AC	0.50	$7,500.00	$3,750.00
3	Construction Survey and Stakeout		LS	1.00	$5,000.00	$5,000.00
4	Bulk Excavation		CY	7,000.00	$4.00	$28,000.00
5	Outlet Structure		LS	1.00	$5,000.00	$5,000.00
6	Rip-rap Erosion Protection		CY	400.00	$65.00	$26,000.00
7	Erosion and Sedimentation Control		LS	1.00	$6,000.00	$6,000.00
8	Fencing		LF	1,500.00	$2.00	$3,000.00
9	Access Gates		EA	2.00	$2,000.00	$4,000.00
10	Permanent Seeding and Mulching		AC	2.00	$3,000.00	$6,000.00
11	Tree, Shrub, and Aquatic Plantings		AC	0.50	$20,000.00	$10,000.00
12	Incidental Property/ Site Improvements		LS	1.00	$5000.00	$5,000.00
13	As-Built Drawings		LS	1.00	$5,000.00	$5,000.00
	Sub-Total of Construction Costs:					$112,750.00
	Construction Costs Contingency				20%	$22,550.00
	Total of Construction Costs:					$135,300.00
	Operations and Maintenance Cost Estimate					
	Operations and Maintenance Cost Estimate as a Percentage of the Construction Costs				5%	$6,765.00
	TOTAL ESTIMATED PROJECT COST:					**$194,065.00**

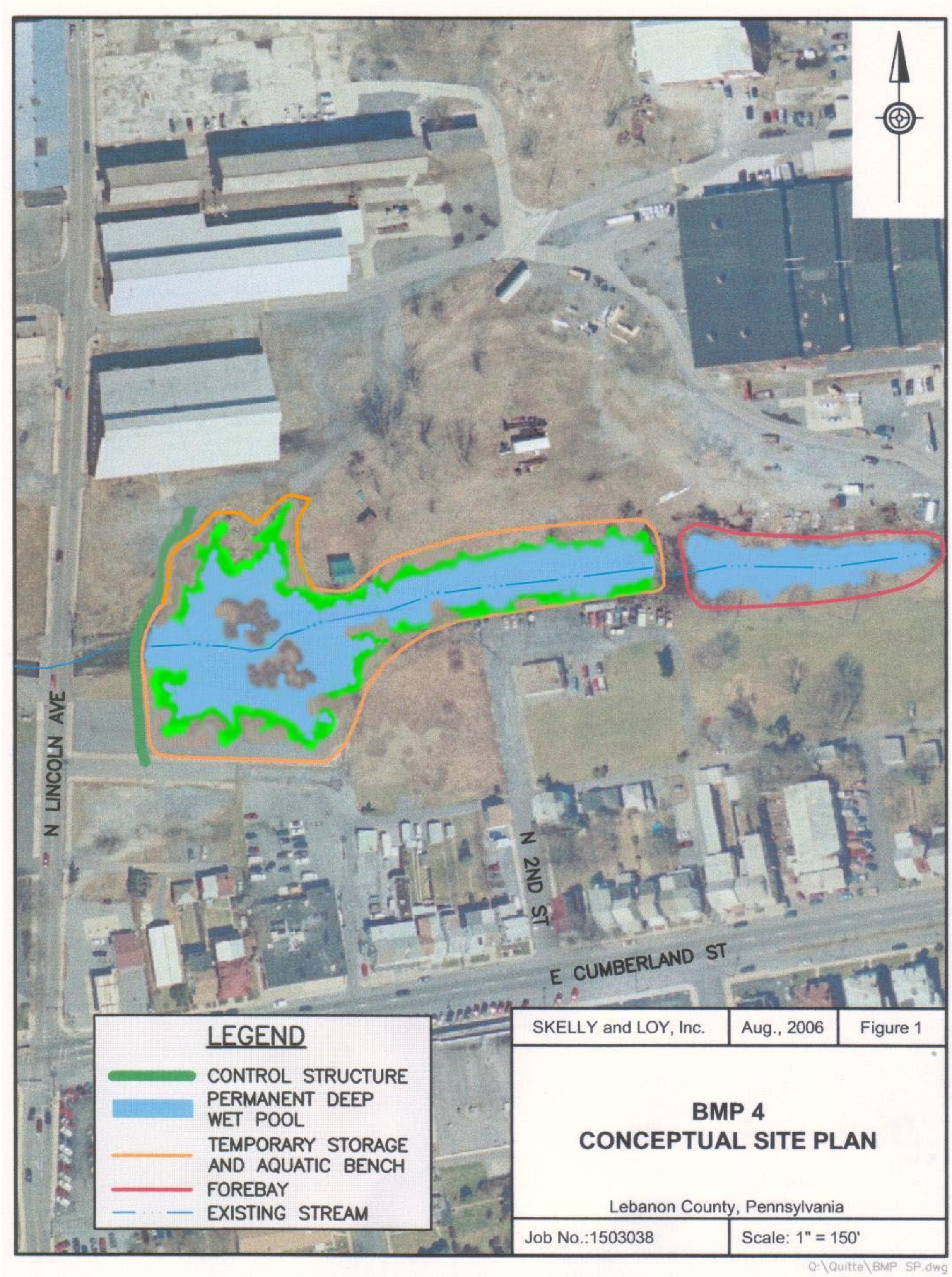


Figure 3.8 – Concept Design for BMP 4

BMP Site Location: 5

Sub-Watershed: 17

Total Drainage Area: 2.03 sq. mi.
Watershed Percent Impervious: 5%

SUB-BASIN

The contributing drainage area to BMP Site 5 is approximately 2.03 sq. mi. (1,302 acres). BMP Site 5 is located within the eastern portion of sub-watershed 17 of the Quittapahilla Creek watershed. The land use in this sub-basin is principally agricultural with strong residential development growth occurring.

SITE LOCATION

This site is located on the Lebanon Vo-Tech School property immediately downstream of Metro Drive. Although the site has already been developed as a wetland-wildlife area, it could be expanded and upgraded to provide regional water quality and quantity management for stormwater runoff from this rapidly developing subwatershed.

DESIGN INFORMATION

Site 5 is a proposed 7.58 acre wet pond BMP with a 6.08 acre permanent pool at a maximum depth of 5 ft, with a proposed storage volume of 25.52 acre-feet. The forebay would equal 10-15% of the total proposed water quality volume, or between 1.52 and 2.28 acre-feet. The control structure would be a single control outlet through an earthen berm and a larger spillway at the top of the berm for passage of more severe storm event flows. These structures will maintain an existing base flow and maximize the peak attenuation for the 1.5 year storm event. From the present urbanized conditions to the proposed installation of the wet detention pond BMPs, Site 5 will contribute toward reducing the bankfull discharge flows in the main stem of Quittapahilla Creek to within 10% of the pre-urbanized flow conditions. The Surface Area to Drainage Area Ratio (SA/DA) required for 85% pollution removal for this BMP is 0.16% (estimated for a 5' maximum depth permanent pool). However, the Surface Area to Drainage Area Ratio for BMP Site 5 is 0.00467, which indicates a removal efficiency of 85%. Design information is summarized in Table 3.14 and Figure 3.9 illustrates the concept design and site location for the proposed BMP.

Construction would also include the installation of buffer plantings, landscaping and slope stabilization. Property Owner/Parcel Information was not determined. However, the site may require the acquisition of private parcels and/or easements belonging to property owners who are not currently involved with this project. Construction cost estimate for this facility is detailed in Table 3.15.

Table 3.14 – Site 5 Proposed BMP Design Parameters Summary	
Design Parameter	**System Total**
Permanent Pool Surface Area, acre	6.08
Total Drainage Area, acre	1,302
Impervious Area, acre	65
SA/DA, percent	0.467%
Proposed Storage Volume, acre-ft	25.52
Control Structure	Stabilized Overflow Crest w/ Emergency Spillway
Pollutant Removal Efficiency, percent	85%
Estimated Cost, $	$190,845.00

Table 3.15 – Site 5 Cost Estimate – Extended Detention Wet

Item No.	Description		Units	Quantity	Unit Price	Total Price
	Engineering Phase Cost Estimate					
1	Base Survey with Topography and Property Delineations		LS	1.00	$5,000.00	$5,000.00
2	Engineering Design		LS	1.00	$20,000.00	$20,000.00
3	Permit Application and Securement		LS	1.00	$15,000.00	$15,000.00
4	Construction/ Permanent Easements and Associated Fees		LS	1.00	$5,000.00	$5,000.00
	Total of Engineering Costs:					$45,000.00
	Construction Phase Cost Estimate					
1	Mobilization/Demobilization		LS	1.00	$6,000.00	$6,000.00
2	Clearing and Grubbing		AC	0.50	$7,500.00	$3,750.00
3	Construction Survey and Stakeout		LS	1.00	$5,000.00	$5,000.00
4	Bulk Excavation		CY	5,000.00	$4.00	$20,000.00
5	Outlet Structure		LS	1.00	$5,000.00	$5,000.00
6	Rip-rap Erosion Protection		CY	400.00	$65.00	$26,000.00
7	Erosion and Sedimentation Control		LS	1.00	$6,000.00	$6,000.00
8	Fencing		LF	3,000.00	$2.00	$6,000.00
9	Access Gates		EA	2.00	$2,000.00	$4,000.00
10	Permanent Seeding and Mulching		AC	1.00	$3,000.00	$3,000.00
11	Tree, Shrub, and Aquatic Plantings		AC	1.00	$20,000.00	$20,000.00
12	Incidental Property/ Site Improvements		LS	1.00	$5,000.00	$5,000.00
13	As-Built Drawings		LS	1.00	$6,000.00	$6,000.00
	Sub-Total of Construction Costs:					$115,750.00
	Construction Costs Contingency				20%	$23,150.00
	Total of Construction Costs:					$138,900.00
	Operations and Maintenance Cost Estimate					
	Operations and Maintenance Cost Estimate as a Percentage of the Construction Costs				5%	$6,945.00
	TOTAL ESTIMATED PROJECT COST:					**$190,845.00**

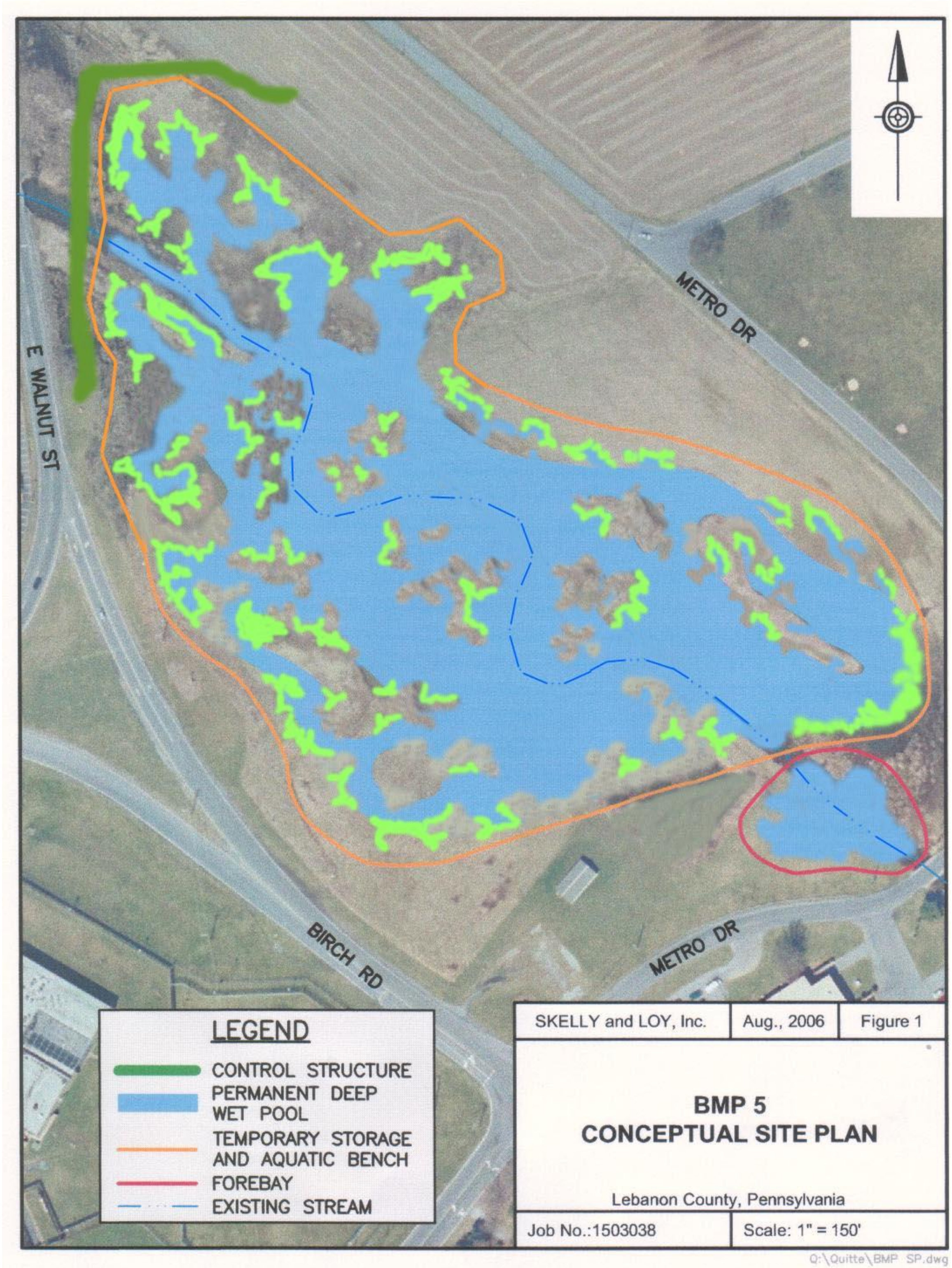


Figure 3.9 – Concept Design for BMP 5

BMP Site Location: 6A

Sub-Watershed: 16

Total Drainage Area: 1.30 sq. mi.
Watershed Percent Impervious: 15%

SUB-BASIN

The contributing drainage area to BMP Site 6A is approximately 1.30 sq. mi. (830 acres). BMP Site 6A is located within the northwestern portion of sub-watershed 16 of the Quittapahilla Creek watershed. The drainage area contributing runoff to this BMP site location is principally agricultural land use

SITE LOCATION

This site is located on a farm north of Wilhelm Avenue. It is bounded on the west by an old railroad bed and Lebanon High School. It is bounded on the east by residential subdivisions along Foxchase Lane, S. 3rd Street and Sun Circle. The site is currently cultivated land.

DESIGN INFORMATION

Site 6A is a proposed 24.63 acre wet pond BMP with a 21.86 acre permanent pool at a maximum depth of 5 ft, with a proposed storage volume of 66.81 acre-feet. The forebay would equal 10-15% of the total proposed water quality volume, or between 5.46 and 8.20 acre-feet. The control structure would be a single control outlet through an earthen berm and a larger spillway at the top of the berm for passage of more severe storm event flows. These structures will maintain an existing base flow and maximize the peak attenuation for the 1.5 year storm event. From the present urbanized conditions to the proposed installation of the wet detention pond BMPs, Site 6A will contribute toward reducing the bankfull discharge flows in the main stem of Quittapahilla Creek to within 10% of the pre-urbanized flow conditions. The Surface Area to Drainage Area Ratio (SA/DA) required for 85% pollution removal for this BMP is 0.57% (estimated for a 5' maximum depth permanent pool). However, the Surface Area to Drainage Area Ratio for BMP Site 6A is 0.0263, which indicates a removal efficiency of 85%. Design information is summarized in Table 3.16 and Figure 3.10 illustrates the concept design and site location for the proposed BMP.

Construction would also include the installation of buffer plantings, landscaping and slope stabilization. Property Owner/Parcel Information was not determined. However, the site may require the acquisition of private parcels and/or easements belonging to property owners who are not currently involved with this project. Construction cost estimate for this facility is detailed in Table 3.17.

Table 3.16 – Site 6A Proposed BMP Design Parameters Summary	
Design Parameter	**System Total**
Permanent Pool Surface Area, acre	21.86
Total Drainage Area, acre	830
Impervious Area, acre	125
SA/DA, percent	2.63%
Proposed Storage Volume, acre-ft	66.81
Control Structure	Stabilized Overflow Crest w/ Emergency Spillway
Pollutant Removal Efficiency, percent	85%
Estimated Cost, $	$679,132.50

Table 3.17 – Site 6A Cost Estimate – Extended Detention Wet						
Item No.	**Description**		**Units**	**Quantity**	**Unit Price**	**Total Price**
	Engineering Phase Cost Estimate					
1	Base Survey with Topography and Property Delineations		LS	1.00	$10,000.00	$10,000.00
2	Engineering Design		LS	1.00	$20,000.00	$20,000.00
3	Permit Application and Securement		LS	1.00	$15,000.00	$15,000.00
4	Construction/ Permanent Easements and Associated Fees		LS	1.00	$15,000.00	$15,000.00
	Total of Engineering Costs:					$60,000.00
	Construction Phase Cost Estimate					
1	Mobilization/Demobilization		LS	1.00	$6,000.00	$6,000.00
2	Clearing and Grubbing		AC	0.25	$7,500.00	$1,875.00
3	Construction Survey and Stakeout		LS	1.00	$5,000.00	$5,000.00
4	Bulk Excavation		CY	59,000.00	$4.00	$236,000.00
5	Outlet Structure		LS	1.00	$8,000.00	$8,000.00
6	Rip-rap Erosion Protection		CY	500.00	$65.00	$32,500.00
7	Erosion and Sedimentation Control		LS	1.00	$12,000.00	$12,000.00
8	Fencing		LF	5,000.00	$2.00	$10,000.00
9	Access Gates		EA	2.00	$2,000.00	$4,000.00
10	Permanent Seeding and Mulching		AC	20.00	$3,000.00	$60,000.00
11	Tree, Shrub, and Aquatic Plantings		AC	5.00	$20,000.00	$100,000.00
12	Incidental Property/ Site Improvements		LS	1.00	$10,000.00	$10,000.00
13	As-Built Drawings		LS	1.00	$6,000.00	$6,000.00
	Sub-Total of Construction Costs:					$491,375.00
	Construction Costs Contingency				20%	$98,275.00
	Total of Construction Costs:					$589,650.00
	Operations and Maintenance Cost Estimate					
	Operations and Maintenance Cost Estimate as a Percentage of the Construction Costs				5%	$29,482.50
	TOTAL ESTIMATED PROJECT COST:					**$679,132.50**

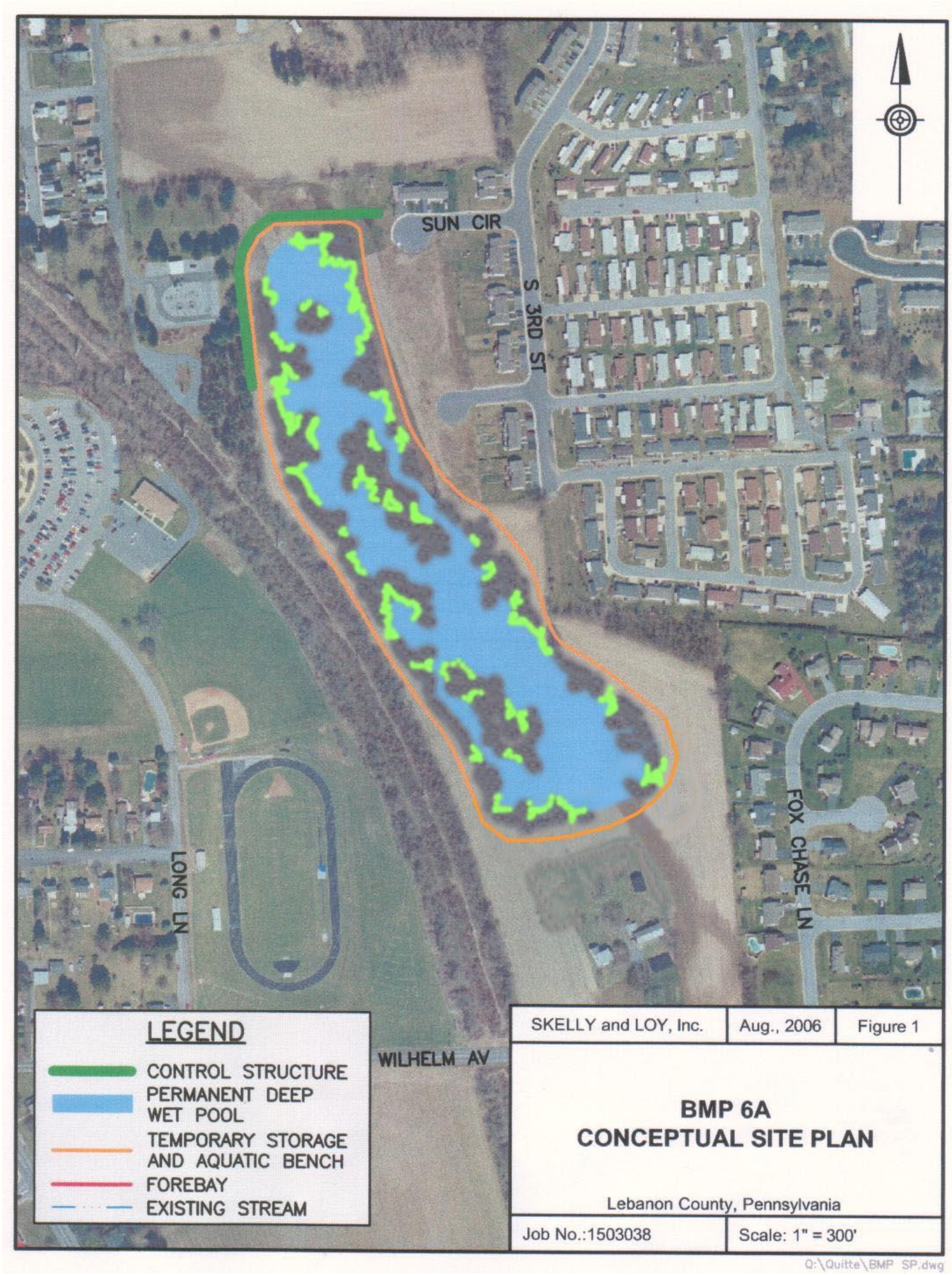


Figure 3.10 – Concept Design for BMP 6A

BMP Site Location: 8

Sub-Watershed: 15

Total Drainage Area: 2.14 sq.mi.
Watershed Percent Impervious: 40%

SUB-BASIN

The contributing drainage area to BMP Site 8 is approximately 2.14 square miles (1,371 acres). BMP Site 8 is located within the southern portion of sub-watershed 15 of the Quittapahilla Creek watershed. The land use in this sub-watershed is single and multi-family residential as well as agriculture

SITE LOCATION

The site is located in the lower Brandywine Creek watershed immediately north of Maple Street. It is bounded on the north and west by residential subdivisions along Steckbeck and North 10th Streets and Coleman Circle. It is bounded on the east by a forested slope along Hill Street. The site is currently a mowed field beneath which Brandywine Creek is conveyed in a piped system that conveys it approximately 2000 feet before day-lighting at 12th Street. The project would require day-lighting approximately 1200 feet of the creek.

DESIGN INFORMATION

Site 8 is a proposed 5.19 acre wet pond BMP with a 3.96 acre permanent pool at a maximum depth of 3 ft, with a proposed storage volume of 2.00 acre-feet. The forebay would equal 10-15% of the total proposed water quality volume, or between 0.59 and 0.89 acre-feet. The control structure would be a single control outlet through an earthen berm and a larger spillway at the top of the berm for passage of more severe storm event flows. These structures will maintain an existing base flow and maximize the peak attenuation for the 1.5 year storm event. From the present urbanized conditions to the proposed installation of the wet detention pond BMPs, Site 8 will contribute toward reducing the bankfull discharge flows in the main stem of Quittapahilla Creek to within 10% of the pre-urbanized flow conditions. The Surface Area to Drainage Area Ratio (SA/DA) required for 85% pollution removal for this BMP is 1.73% (estimated for a 3' maximum depth permanent pool). However, the Surface Area to Drainage Area Ratio for BMP Site 8 is 0.00289, which indicates a removal efficiency of 17%. Design information is summarized in Table 3.18 and Figure 3.11 illustrates the concept design and site location for the proposed BMP.

Construction would also include the installation of buffer plantings, landscaping and slope stabilization. Property Owner/Parcel Information was not determined. However, the site may require the acquisition of private parcels and/or easements belonging to property owners who are not currently involved with this project. Construction cost estimate for this facility is detailed in Table 3.19.

Table 3.18 – Site 8 Proposed BMP Design Parameters Summary	
Design Parameter	**System Total**
Permanent Pool Surface Area, acre	3.96
Total Drainage Area, acre	1,371
Impervious Area, acre	548
SA/DA, percent	0.289%
Proposed Storage Volume, acre-ft	2.00
Control Structure	Stabilized Overflow Crest w/ Emergency Spillway
Pollutant Removal Efficiency, percent	17%
Estimated Cost, $	$302,825.00

Table 3.19 – Site 8 Cost Estimate – Extended Detention Wet

Item No.	Description		Units	Quantity	Unit Price	Total Price
	Engineering Phase Cost Estimate					
1	Base Survey with Topography and Property Delineations		LS	1.00	$10,000.00	$10,000.00
2	Engineering Design		LS	1.00	$20,000.00	$20,000.00
3	Permit Application and Securement		LS	1.00	$15,000.00	$15,000.00
4	Construction/ Permanent Easements and Associated Fees		LS	1.00	$20,000.00	$20,000.00
	Total of Engineering Costs:					$65,000.00
	Construction Phase Cost Estimate					
1	Mobilization/Demobilization		LS	1.00	$8,000.00	$8,000.00
2	Clearing and Grubbing		AC	0.50	$7,500.00	$3,750.00
3	Construction Survey and Stakeout		LS	1.00	$10,000.00	$10,000.00
4	Bulk Excavation		CY	10,000.00	$4.00	$40,000.00
5	Outlet Structure		LS	1.00	$5,000.00	$5,000.00
6	Rip-rap Erosion Protection		CY	400.00	$65.00	$26,000.00
7	Erosion and Sedimentation Control		LS	1.00	$12,000.00	$12,000.00
8	Fencing		LF	3,000.00	$2.00	$6,000.00
9	Access Gates		EA	2.00	$2,000.00	$4,000.00
10	Permanent Seeding and Mulching		AC	6.00	$3,000.00	$18,000.00
11	Tree, Shrub, and Aquatic Plantings		AC	2.00	$20,000.00	$40,000.00
12	Incidental Property/ Site Improvements		LS	1.00	$10,000.00	$10,000.00
13	As-Built Drawings		LS	1.00	$6,000.00	$6,000.00
	Sub-Total of Construction Costs:					$188,750.00
	Construction Costs Contingency				20%	$37,750.00
	Total of Construction Costs:					$226,500.00
	Operations and Maintenance Cost Estimate					
	Operations and Maintenance Cost Estimate as a Percentage of the Construction Costs				5%	$11,325.00
	TOTAL ESTIMATED PROJECT COST:					**$302,825.00**

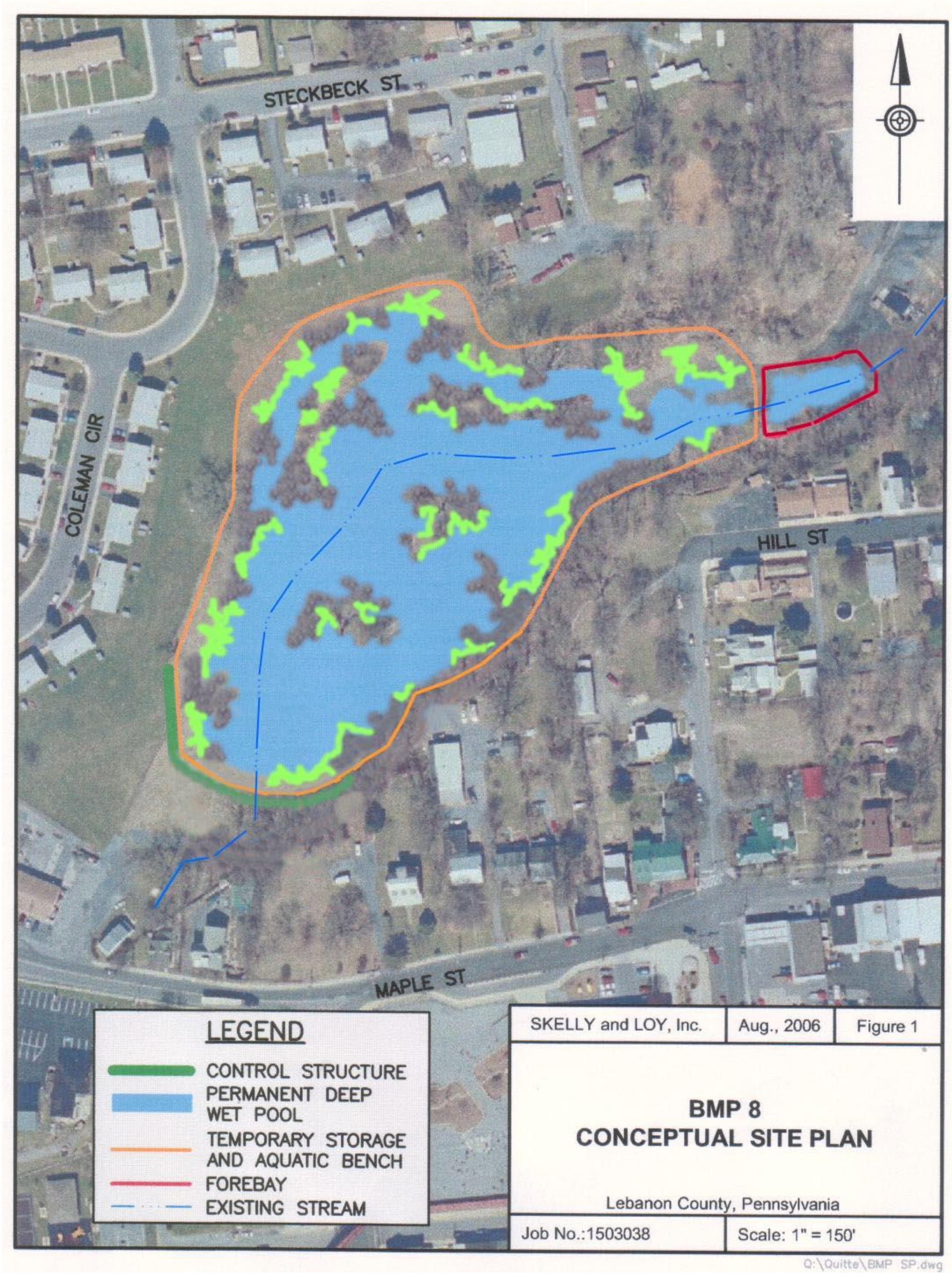


Figure 3.11 – Concept Design for BMP 8

BMP Site Location: 9

Sub-Watershed: 15

Total Drainage Area: 1.74 sq. mi.
Watershed Percent Impervious: 20%

SUB-BASIN

The contributing drainage area to BMP Site 9 is approximately 1.74 sq. mi. (1,115 acres). BMP Site 9 is located within the southern portion of sub-watershed 15 of the Quittapahilla Creek watershed. The land use in this sub-watershed is single and multi-family residential as well as agriculture.

SITE LOCATION

The site is located on the main stem Brandywine Creek immediately upstream of North 8th Street. It is bounded on the north by a wooded slope and field at the top of slope with an electric substation and parking lot. To the south is a wooded slope. At North 8th Street Brandywine Creek enters a piped system that conveys it approximately 2000 feet before day-lighting at 12th Street.

DESIGN INFORMATION

Site 9 is a proposed 1.18 acre wet pond BMP with a 0.64 acre permanent pool at a maximum depth of 5 ft, with a proposed storage volume of 3.00 acre-feet. The forebay would equal 10-15% of the total proposed water quality volume, or between 0.16 and 0.24 acre-feet. The control structure would be a single control outlet through an earthen berm and a larger spillway at the top of the berm for passage of more severe storm event flows. These structures will maintain an existing base flow and maximize the peak attenuation for the 1.5 year storm event. From the present urbanized conditions to the proposed installation of the wet detention pond BMPs, Site 9 will contribute toward reducing the bankfull discharge flows in the main stem of Quittapahilla Creek to within 10% of the pre-urbanized flow conditions. The Surface Area to Drainage Area Ratio (SA/DA) required for 85% pollution removal for this BMP is 0.70% (estimated for a 5' maximum depth permanent pool). However, the Surface Area to Drainage Area Ratio for BMP Site 9 is 0.000574, which indicates a removal efficiency of 8%. Design information is summarized in Table 3.20 and Figure 3.12 illustrates the concept design and site location for the proposed BMP.

Construction would also include the installation of buffer plantings, landscaping and slope stabilization. Property Owner/Parcel Information was not determined. However, the site may require the acquisition of private parcels and/or easements belonging to property owners who are not currently involved with this project. Construction cost estimate for this facility is detailed in Table 3.21.

Table 3.20 – Site 9 Proposed BMP Design Parameters Summary	
Design Parameter	**System Total**
Permanent Pool Surface Area, acre	0.64
Total Drainage Area, acre	1,115
Impervious Area, acre	223
SA/DA, percent	0.0574%
Proposed Storage Volume, acre-ft	3.00
Control Structure	Stabilized Overflow Crest w/ Emergency Spillway
Pollutant Removal Efficiency, percent	8%
Estimated Cost, $	$212,570.00

Table 3.21 – Site 9 Cost Estimate – Extended Detention Wet					
Item No.	**Description**	**Units**	**Quantity**	**Unit Price**	**Total Price**
	Engineering Phase Cost Estimate				
1	Base Survey with Topography and Property Delineations	LS	1.00	$12,000.00	$12,000.00
2	Engineering Design	LS	1.00	$20,000.00	$20,000.00
3	Permit Application and Securement	LS	1.00	$15,000.00	$15,000.00
4	Construction/ Permanent Easements and Associated Fees	LS	1.00	$15,000.00	$15,000.00
	Total of Engineering Costs:				$62,000.00
	Construction Phase Cost Estimate				
1	Mobilization/Demobilization	LS	1.00	$6,000.00	$6,000.00
2	Clearing and Grubbing	AC	2.00	$7,500.00	$15,000.00
3	Construction Survey and Stakeout	LS	1.00	$7,000.00	$7,000.00
4	Bulk Excavation	CY	3,000.00	$4.00	$12,000.00
5	Outlet Structure	LS	1.00	$5,000.00	$5,000.00
6	Rip-rap Erosion Protection	CY	300.00	$65.00	$19,500.00
7	Erosion and Sedimentation Control	LS	1.00	$6,000.00	$6,000.00
8	Fencing	LF	1,500.00	$2.00	$3,000.00
9	Access Gates	EA	2.00	$2,000.00	$4,000.00
10	Permanent Seeding and Mulching	AC	2.00	$3,000.00	$6,000.00
11	Tree, Shrub, and Aquatic Plantings	AC	1.00	$20,000.00	$20,000.00
12	Incidental Property/ Site Improvements	LS	1.00	$10,000.00	$10,000.00
13	As-Built Drawings	LS	1.00	$6,000.00	$6,000.00
	Sub-Total of Construction Costs:				$119,500.00
	Construction Costs Contingency			20%	$23,900.00
	Total of Construction Costs:				$143,400.00
	Operations and Maintenance Cost Estimate				
	Operations and Maintenance Cost Estimate as a Percentage of the Construction Costs			5%	$7,170.00
	TOTAL ESTIMATED PROJECT COST:				**$212,570.00**

Figure 3.12 – Concept Design for BMP 9

BMP Site Location: 10

Sub-Watershed: 15

Total Drainage Area: 3.36 sq. mi.
Watershed Percent Impervious: 20%

SUB-BASIN

The contributing drainage area to BMP Site 10 is approximately 3.36 sq. mi. (2,148 acres). BMP Site 10 is located within the southwestern portion of sub-watershed 15 of the Quittapahilla Creek watershed. The land use in this sub-watershed is principally single and multi- family residential as well as agriculture.

SITE LOCATION

This site is located on the main stem Brandywine Creek immediately downstream of Lehman Street. It is bounded on the east, west and south by industrial land and a railroad. At the downstream end of the site Brandywine Creek enters a piped system that conveys it approximately 1500 feet to its confluence with Quittapahilla Creek. The site is currently a gabion lined channel with a wooded floodplain along the right side.

DESIGN INFORMATION

Site 10 is a proposed 5.34 acre wet pond BMP with a 4.10 acre permanent pool at a maximum depth of 5 ft, with a proposed storage volume of 3.00 acre-feet. The forebay would equal 10-15% of the total proposed water quality volume, or between 0.16 and 0.24 acre-feet. The control structure would be a single control outlet through an earthen berm and a larger spillway at the top of the berm for passage of more severe storm event flows. These structures will maintain an existing base flow and maximize the peak attenuation for the 1.5 year storm event. From the present urbanized conditions to the proposed installation of the wet detention pond BMPs, Site 10 will contribute toward reducing the bankfull discharge flows in the main stem of Quittapahilla Creek to within 10% of the pre-urbanized flow conditions. The Surface Area to Drainage Area Ratio (SA/DA) required for 85% pollution removal for this BMP is 0.70% (estimated for a 5' maximum depth permanent pool). However, the Surface Area to Drainage Area Ratio for BMP Site 10 is 0.00191, which indicates a removal efficiency of 27%. Design information is summarized in Table 3.22 and Figure 3.13 illustrates the concept design site location for the proposed BMP.

Construction would also include the installation of buffer plantings, landscaping and slope stabilization. Property Owner/Parcel Information was not determined. However, the site may require the acquisition of private parcels and/or easements belonging to property owners who are not currently involved with this project. Construction cost estimate for this facility is detailed in Table 3.23.

Table 3.22 – Site 10 Proposed BMP Design Parameters Summary	
Design Parameter	**System Total**
Permanent Pool Surface Area, acre	4.10
Total Drainage Area, acre	2,148
Impervious Area, acre	430
SA/DA, percent	0.191%
Proposed Storage Volume, acre-ft	3.00
Control Structure	Stabilized Overflow Crest w/ Emergency Spillway
Pollutant Removal Efficiency, percent	27%
Estimated Cost, $	$368,180.00

Table 3.23 – Site 10 Cost Estimate – Extended Detention Wet

Item No.	Description		Units	Quantity	Unit Price	Total Price
	Engineering Phase Cost Estimate					
1	Base Survey with Topography and Property Delineations		LS	1.00	$12,000.00	$12,000.00
2	Engineering Design		LS	1.00	$20,000.00	$20,000.00
3	Permit Application and Securement		LS	1.00	$15,000.00	$15,000.00
4	Construction/ Permanent Easements and Associated Fees		LS	1.00	$15,000.00	$15,000.00
	Total of Engineering Costs:					$62,000.00
	Construction Phase Cost Estimate					
1	Mobilization/Demobilization		LS	1.00	$7,000.00	$7,000.00
2	Clearing and Grubbing		AC	6.00	$7,500.00	$45,000.00
3	Construction Survey and Stakeout		LS	1.00	$10,000.00	$10,000.00
4	Bulk Excavation		CY	11,000.00	$4.00	$44,000.00
5	Outlet Structure		LS	1.00	$5,000.00	$5,000.00
6	Rip-rap Erosion Protection		CY	400.00	$65.00	$26,000.00
7	Erosion and Sedimentation Control		LS	1.00	$10,000.00	$10,000.00
8	Fencing		LF	2,000.00	$2.00	$4,000.00
9	Access Gates		EA	2.00	$2,000.00	$4,000.00
10	Permanent Seeding and Mulching		AC	4.00	$3,000.00	$12,000.00
11	Tree, Shrub, and Aquatic Plantings		AC	3.00	$20,000.00	$60,000.00
12	Incidental Property/ Site Improvements		LS	1.00	$10,000.00	$10,000.00
13	As-Built Drawings		LS	1.00	$6,000.00	$6,000.00
	Sub-Total of Construction Costs:					$243,000.00
	Construction Costs Contingency				20%	$48,600.00
	Total of Construction Costs:					$291,600.00
	Operations and Maintenance Cost Estimate					
	Operations and Maintenance Cost Estimate as a Percentage of the Construction Costs				5%	$14,580.00
	TOTAL ESTIMATED PROJECT COST:					**$368,180.00**

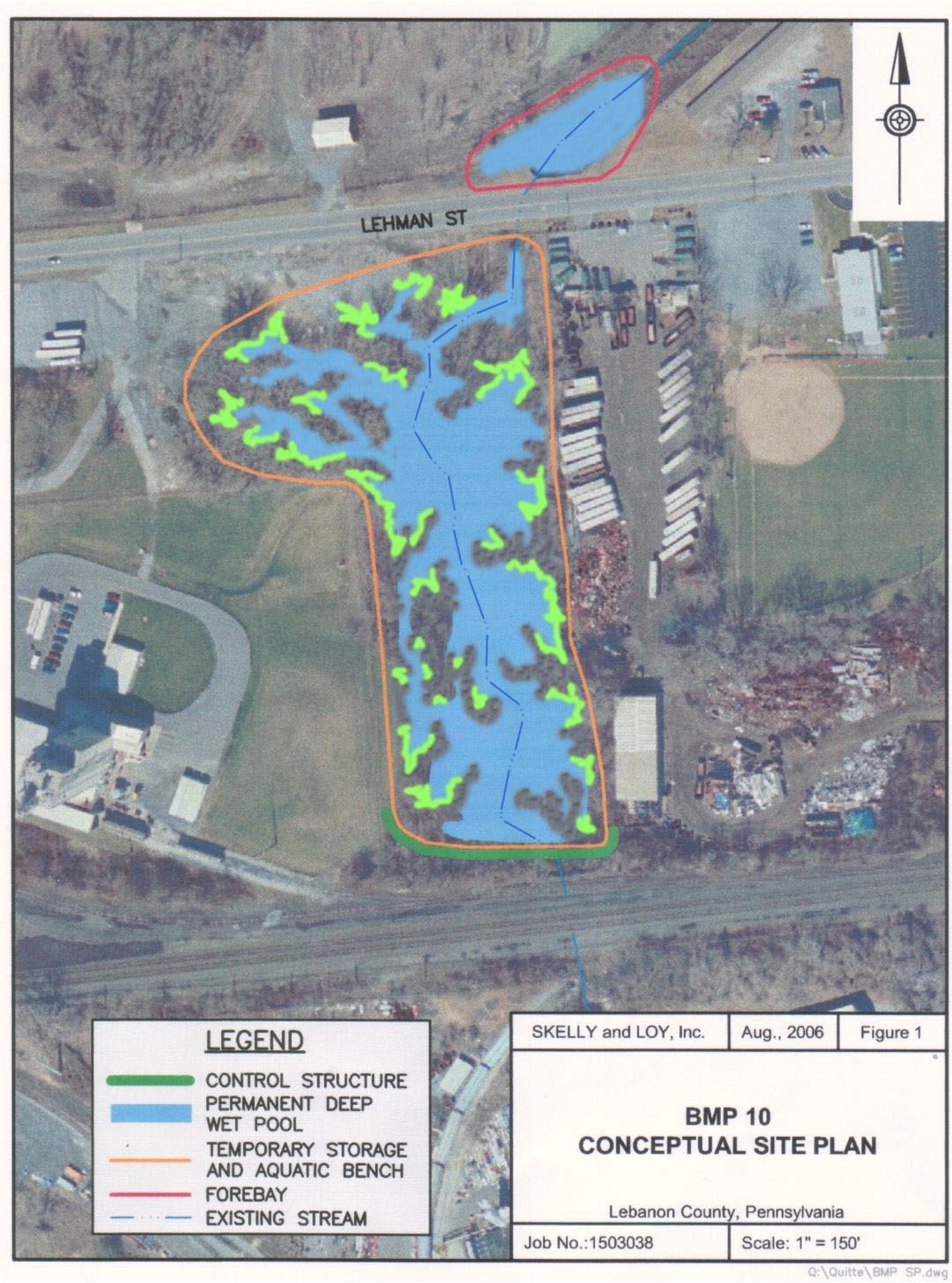


Figure 3.13 – Concept Design for BMP 10

BMP Site Location: 11

Sub-Watershed: 15

Total Drainage Area: 0.28 sq. mi.
Watershed Percent Impervious: 50%

SUB-BASIN

The contributing drainage area to BMP Site 11 is approximately 0.28 sq. mi. (180 acres). BMP Site 11 is located in the central portion of sub-watershed 15 of the Quittapahilla Creek watershed. The land use in the portions of this sub-watershed upstream of the BMP site is principally single family residential and agriculture.

SITE LOCATION

The site is located on a tributary to Brandywine Creek between Mechanic Street and Reinoehl Street. It is bounded on the east and west by wooded slopes and single family homes at the top of the slopes. The site is currently forest with old ponds along the floodplain.

DESIGN INFORMATION

Site 11 is proposed to include three (3) wetland ponds in series with a total surface area of 1.68 acres and a total permanent pool area of 1.02 acres at a maximum depth of 5 ft, with a proposed total storage volume of 3.51 acre-feet. The forebay would equal 10-15% of the total proposed water quality volume, or between 0.25 and 0.38 acre-feet. The control structures in each of the series of basins will be a single control outlet through an earthen berm and a larger spillway at the top of the berm for passage of more severe storm event flows. These structures will maintain an existing base flow and maximize the peak attenuation for the 1.5 year storm event. From the present urbanized conditions to the proposed installation of the wet detention pond BMPs, Site 11 will contribute toward reducing the bankfull discharge flows in the main stem of Quittapahilla Creek to within 10% of the pre-urbanized flow conditions. The Surface Area to Drainage Area Ratio (SA/DA) required for 85% pollution removal for this BMP is 1.11% (estimated for a 5' maximum depth permanent pool). However, the Surface Area to Drainage Area Ratio for BMP Site 11 is 0.00567, which indicates a removal efficiency of 51%. Design information is summarized in Table 3.24 and Figure 3.14 illustrates the concept design and site location for the proposed BMP.

Construction would also include the installation of buffer plantings, landscaping and slope stabilization. Property Owner/Parcel Information was not determined. However, the site may require the acquisition of private parcels and/or easements belonging to property owners who are not currently involved with this project. Construction cost estimate for this facility is detailed in Table 3.25.

Table 3.24 – Site 11 Proposed BMP Design Parameters Summary	
Design Parameter	**System Total**
Permanent Pool Surface Area, acre	1.02
Total Drainage Area, acre	180
Impervious Area, acre	90
SA/DA, percent	0.567%
Proposed Storage Volume, acre-ft	3.51
Control Structure	Stabilized Overflow Crest w/ Emergency Spillway
Pollutant Removal Efficiency, percent	51%
Estimated Cost, $	$320,718.00

Table 3.25 – Site 11 Cost Estimate – Extended Detention Wet

Item No.	Description	Units	Quantity	Unit Price	Total Price
	Engineering Phase Cost Estimate				
1	Base Survey with Topography and Property Delineations	LS	1.00	$10,000.00	$10,000.00
2	Engineering Design	LS	1.00	$20,000.00	$20,000.00
3	Permit Application and Securement	LS	1.00	$12,000.00	$12,000.00
4	Construction/ Permanent Easements and Associated Fees	LS	1.00	$15,000.00	$15,000.00
	Total of Engineering Costs:				$57,000.00
	Construction Phase Cost Estimate				
1	Mobilization/Demobilization	LS	1.00	$6,000.00	$6,000.00
2	Clearing and Grubbing	AC	3.00	$7,500.00	$22,500.00
3	Construction Survey and Stakeout	LS	1.00	$10,000.00	$10,000.00
4	Bulk Excavation	CY	2,700.00	$4.00	$10,800.00
5	Outlet Structure	LS	4.00	$5,000.00	$20,000.00
6	Rip-rap Erosion Protection	CY	400.00	$65.00	$26,000.00
7	Erosion and Sedimentation Control	LS	1.00	$10,000.00	$10,000.00
8	Fencing	LF	3,000.00	$2.00	$6,000.00
9	Access Gates	EA	4.00	$2,000.00	$8,000.00
10	Permanent Seeding and Mulching	AC	4.00	$3,000.00	$12,000.00
11	Tree, Shrub, and Aquatic Plantings	AC	3.00	$20,000.00	$60,000.00
12	Incidental Property/ Site Improvements	LS	1.00	$12,000.00	$12,000.00
13	As-Built Drawings	LS	1.00	$6,000.00	$6,000.00
	Sub-Total of Construction Costs:				$209,300.00
	Construction Costs Contingency			20%	$41,860.00
	Total of Construction Costs:				$251,160.00
	Operations and Maintenance Cost Estimate				
	Operations and Maintenance Cost Estimate as a Percentage of the Construction Costs			5%	$12,558.00
	TOTAL ESTIMATED PROJECT COST:				**$320,718.00**

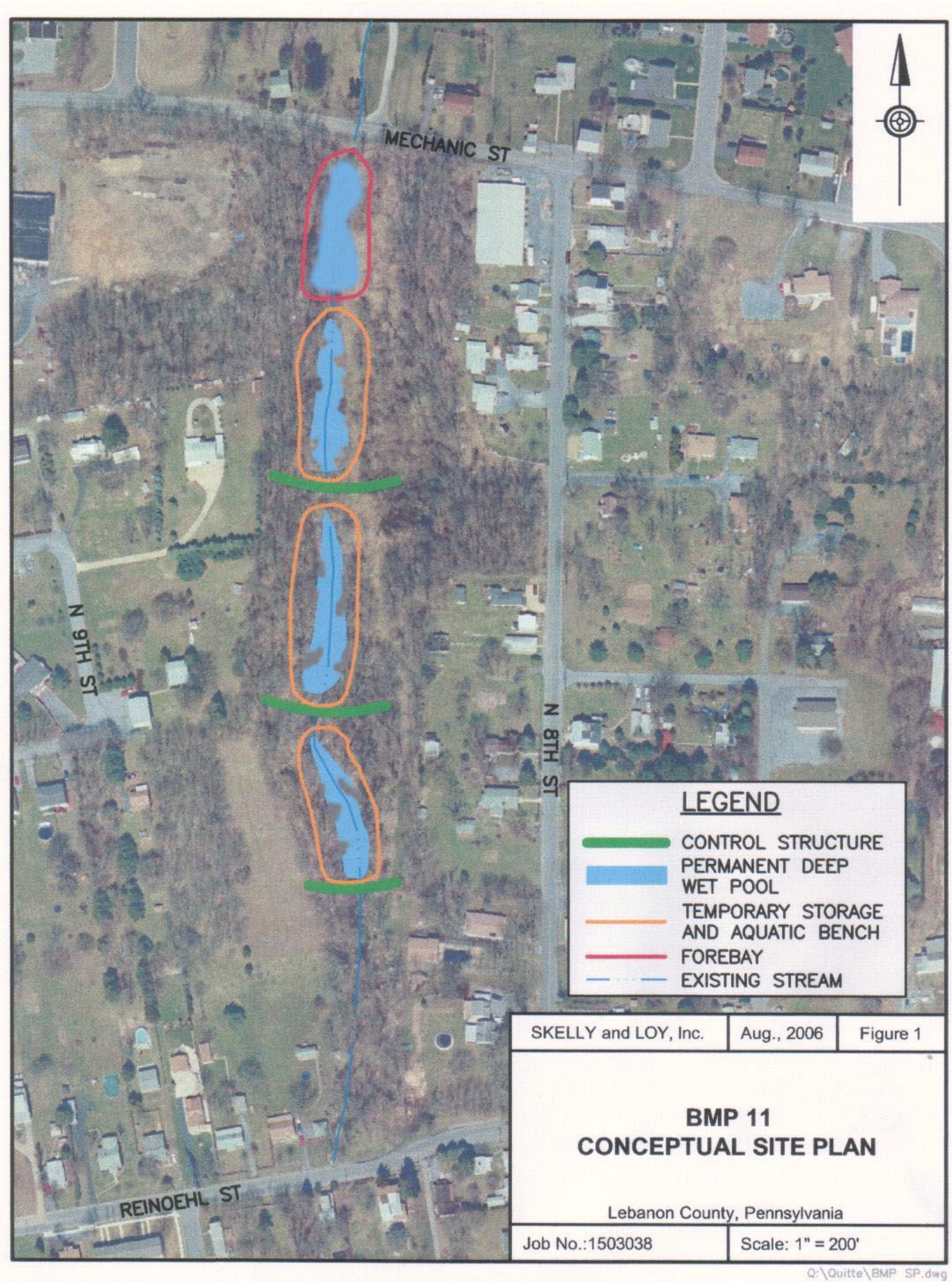


Figure 3.14 – Concept Design for BMP 11

BMP Site Location: 12

Sub-Watershed: 16

Total Drainage Area: 6.46 sq. mi.
Watershed Percent Impervious: 10%

SUB-BASIN

The contributing drainage area to BMP Site 12 is approximately 6.46 sq. mi. (4,133 acres). BMP Site 12 is located within the northeastern portion of sub-watershed 16 of the Quittapahilla Creek watershed. The land use in the contributing watershed area is principally in agriculture, with single family residential, institutional and a golf course.

SITE LOCATION

This site is located on a farm north of Klein Avenue. It is bounded on west and north by residential subdivisions along Kiner and Beechwood Avenues and to the south by farm fields. The site already includes a stormwater management facility that was constructed by the City of Lebanon. It is proposed that the site be expanded and upgraded to provide additional water quality and quantity management for the runoff entering the piped section of the Unnamed Tributary draining South Lebanon.

DESIGN INFORMATION

Site 12 is a proposed 4.10 acre wet pond BMP with a 3.01 acre permanent pool at a maximum depth of 5 ft, with a proposed storage volume of 9.54 acre-feet. The forebay would equal 10-15% of the total proposed water quality volume, or between 0.75 and 1.12 acre-feet. The control structure would be a single control outlet through an earthen berm and a larger spillway at the top of the berm for passage of more severe storm event flows. These structures will maintain an existing base flow and maximize the peak attenuation for the 1.5 year storm event. From the present urbanized conditions to the proposed installation of the wet detention pond BMPs, Site 12 will contribute toward reducing the bankfull discharge flows in the main stem of Quittapahilla Creek to within 10% of the pre-urbanized flow conditions. The Surface Area to Drainage Area Ratio (SA/DA) required for 85% pollution removal for this BMP is 0.43% (estimated for a 5' maximum depth permanent pool). However, the Surface Area to Drainage Area Ratio for BMP Site 12 is 0.000728, which indicates a removal efficiency of 17%. Design information is summarized in Table 3.26 and Figure 3.15 illustrates the concept design and site location for the proposed BMP.

Construction would also include the installation of buffer plantings, landscaping and slope stabilization. Property Owner/Parcel Information was not determined. However, the site may require the acquisition of private parcels and/or easements belonging to property owners who are not currently involved with this project. Construction cost estimate for this facility is detailed in Table 3.27.

Table 3.26 – Site 12 Proposed BMP Design Parameters Summary

Design Parameter	System Total
Permanent Pool Surface Area, acre	3.01
Total Drainage Area, acre	4,133
Impervious Area, acre	413
SA/DA, percent	0.0728%
Proposed Storage Volume, acre-ft	9.54
Control Structure	Stabilized Overflow Crest w/ Emergency Spillway
Pollutant Removal Efficiency, percent	17%
Estimated Cost, $	$243,496.00

Table 3.27 – Site 12 Cost Estimate – Extended Detention Wet

Item No.	Description		Units	Quantity	Unit Price	Total Price
	Engineering Phase Cost Estimate					
1	Base Survey with Topography and Property Delineations		LS	1.00	$10,000.00	$10,000.00
2	Engineering Design		LS	1.00	$20,000.00	$20,000.00
3	Permit Application and Securement		LS	1.00	$15,000.00	$15,000.00
4	Construction/ Permanent Easements and Associated Fees		LS	1.00	$10,000.00	$10,000.00
	Total of Engineering Costs:					$55,000.00
	Construction Phase Cost Estimate					
1	Mobilization/Demobilization		LS	1.00	$6,000.00	$6,000.00
2	Clearing and Grubbing		AC	1.00	$7,500.00	$7,500.00
3	Construction Survey and Stakeout		LS	1.00	$10,000.00	$10,000.00
4	Bulk Excavation		CY	8,000.00	$4.00	$32,000.00
5	Outlet Structure		LS	1.00	$5,000.00	$5,000.00
6	Rip-rap Erosion Protection		CY	300.00	$65.00	$19,500.00
7	Erosion and Sedimentation Control		LS	1.00	$10,000.00	$10,000.00
8	Fencing		LF	2,300.00	$2.00	$4,600.00
9	Access Gates		EA	2.00	$2,000.00	$4,000.00
10	Permanent Seeding and Mulching		AC	5.00	$3,000.00	$12,000.00
11	Tree, Shrub, and Aquatic Plantings		AC	1.00	$20,000.00	$20,000.00
12	Incidental Property/ Site Improvements		LS	1.00	$10,000.00	$10,000.00
13	As-Built Drawings		LS	1.00	$6,000.00	$6,000.00
	Sub-Total of Construction Costs:					149,600.00
	Construction Costs Contingency				20%	$29,920.00
	Total of Construction Costs:					$179,520.00
	Operations and Maintenance Cost Estimate					
	Operations and Maintenance Cost Estimate as a Percentage of the Construction Costs				5%	$8,976.00
	TOTAL ESTIMATED PROJECT COST:					**$243,496.00**

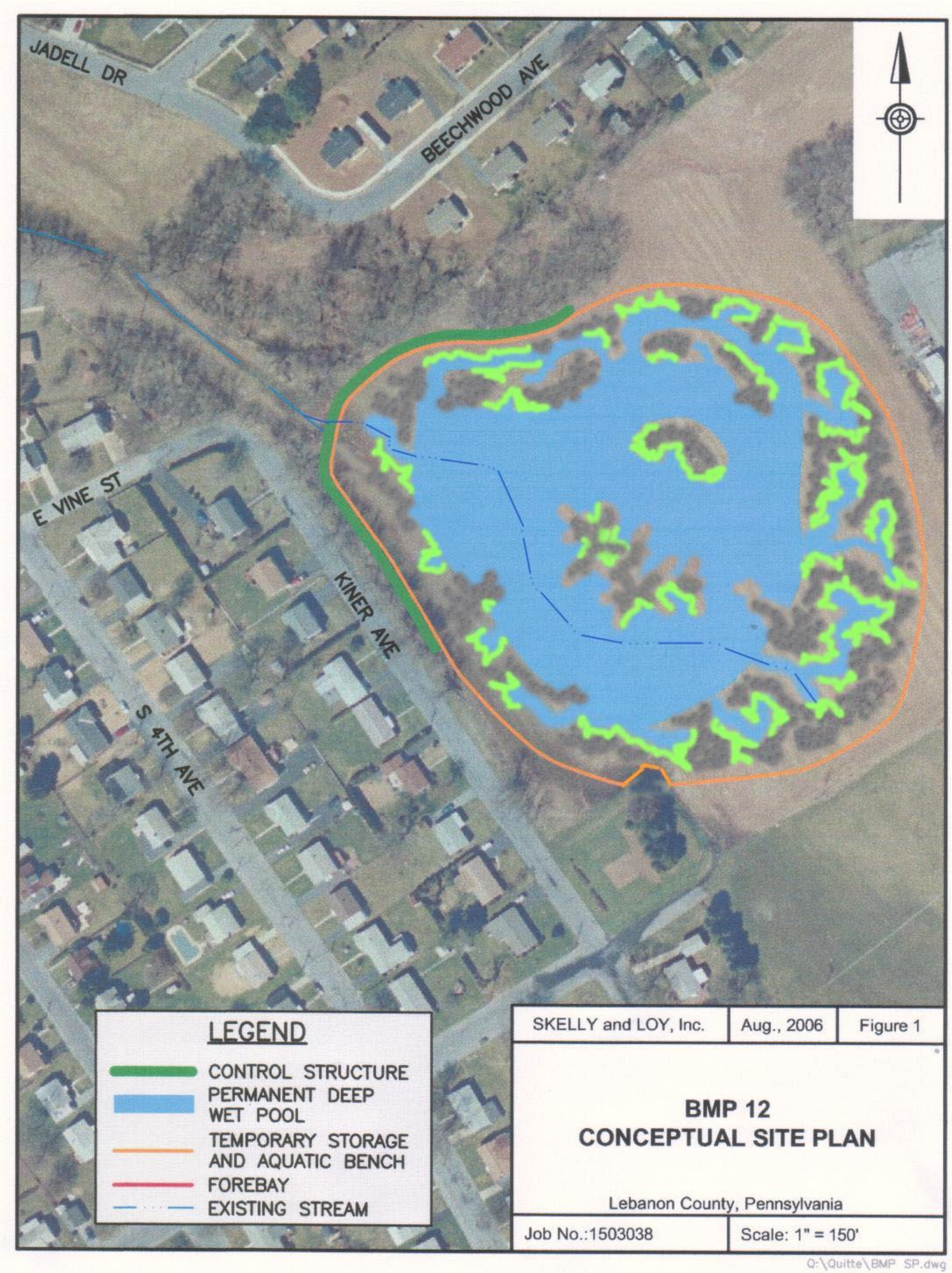


Figure 3.15 – Concept Design for BMP 12

3.3.7 – Prioritization of Urban Best Management Practices

As Table 3.8 shows the combined pollutant reduction effect of implementing the proposed urban best management practices could be significant. The potential benefit is brought into focus if we recall that the results of the water quality modeling show that the Upper Quittapahilla Creek and Brandywine Creek watersheds (i.e., Subwatersheds 15, 16, 17), which account for 23.9% of the total land area in the Quittapahilla Creek watershed, contribute 16.2% of the total nitrogen, 17.7% of the total phosphorus, and 22.9% of the total sediment loadings. The sediment loading estimates developed from the sediment discharge evaluation sampling data support the modeling estimates showing that 20% of the sediment load from the Quittapahilla Creek watershed is contributed by the Upper Quittapahilla Creek and Brandywine Creek watersheds.

Because the maximum pollutant reduction benefit can only be achieved by all of the BMPs functioning in series, it is strongly recommended that all of the proposed Urban Best Management Practices be implemented.

3.3.8 – Stormwater Wetland Permitting Issues

Stormwater wetlands cannot be located within jurisdictional waters, or wetlands without obtaining a section 404 permit under the Clean Water Act and Section 401 Water Quality Certification. BMP sites 2, 3, 4, 5, 8, 9, 10, and 11 are designed as On-Line facilities. From a regulatory perspective there are a number of issues related to designing on-line facilities including impacts to existing wetland and stream resources that must addressed. The following outline indicates potential impacts and briefly addresses their relevance to the on-line facilities proposed for the Upper Quittapahilla Creek and Brandywine Creek subwatersheds.

- Loss of existing wetlands – wetlands do exist at two sites, however they are small and of low quality
- Loss of riparian forest – most sites are open field or lawn, Site 2 is forested, however impacts will be minimized through design
- Loss of in-stream habitat – very little habitat exists at these sites, they include degraded reaches, piped sections, and upland areas (e.g. open fields)
- Fish migration barriers – most sites have existing barriers that can not be removed such as very long piped sections and/or concrete channels with significant drops. Design of the on-line facilities will include a low flow channel through the wetlands except in the fore-bays where the baseflow would pass through an open water area.
- Ponds and shallow water impoundments elevate water temperature – monitoring indicates that existing temperatures along the upper main stem Quittapahilla Creek already exceed the tolerance limits for Trout and most cool water species of fish

The US Environmental Protection Agency and Pennsylvania Department of Environmental Protection require approval of an activity that will result in a change in the Use Classification of a waterbody. An "existing use" is defined in 25 Pa. Code §93.1 as "Those uses actually attained in the water body on or after November 28, 1975, whether or not they are included in the water quality standards". The same definition appears in the federal regulations at 40 CFR §131.3(e). An "existing use" is different than a "designated use." A "designated use" is defined in §93.1 as those uses specified in §§93.9a-93.9z for each waterbody or segment whether or not the use is being attained. Designated uses are regulations promulgated by the Environmental Quality Board (EQB) through the rulemaking process.

Agencies, organizations, and individuals have the option of providing sufficient data to substantiate their position that the existing use differs from the designated use, or providing enough information to establish that the waterbody in question warrants an existing use evaluation.

The following outline indicates “existing” versus “designated” use issues and briefly addresses their relevance to the on-line facilities proposed for the Quittapahilla Creek watershed.

<u>Designated Use</u>

- Quittapahilla Creek is designated as a stocked catch and release trout fishery area

<u>Existing Use</u>

- Main stem Quittapahilla Creek from Snitz Creek downstream is a stocked catch and release trout fishery area, however –

- Upper Quittapahilla Creek where the on-line facilities are proposed is a highly urbanized subwatershed with high percent impervious area, extensive storm drainage and significant length of altered channels (i.e., 80% of stream length is piped or concrete channel). Streambanks along the natural channel reaches between West Lincoln and Rte 422 are composed of slag from old Bethlehem Steel Plant that generates leachate directly into the creek. The streambed along these reaches is composed of unconsolidated clay, gravel, and organic muck. Water quality is poor with elevated levels of nutrients, sediment, heavy metals, coliform bacteria, and temperature. These upper reaches contribute 20% of the nutrient and sediment load from the Quittapahilla Creek watershed

- Brandywine Creek where additional on-line facilities are proposed has a significant length of piped and altered channels in the lower reaches, unstable channel sections in the middle reaches, overall poor water quality, and very little in-stream habitat. Stovers Lake is located in the headwaters of Brandywine Creek

This study has shown that the existing conditions warrant consideration of the use of on-line stormwater wetland facilities along currently degraded reaches in the Upper Quittapahilla Creek and Brandywine Creek subwatersheds that will provide benefits including:

- Significant reduction in nutrients, sediment and heavy metals thereby improving water quality for downstream reaches where in-stream habitat and a healthy biotic community can be maintained
- Recreation of wetlands and active floodplain
- Natural channel sections upstream of the proposed wetland ponds will be restored/stabilized to reduce sediment loadings to the ponds and improve in-stream habitat

Section 4 – Potential Restoration Measures

4.1 General Comments on the Recommended Restoration Approach

4.1.1 Traditional Approaches

The traditional restoration effort is project-oriented rather than system- or process-oriented. The project-oriented approach focuses on the obvious eroding stream banks or aggrading streambeds, and flood waters overtopping stream banks. It often fails to recognize the natural processes that shape and maintain stream channels, the interactions between the channel and adjacent riparian areas, and how these processes and interactions are affected by channel and floodplain maintenance practices and land use in the watershed.

The traditional approach is commonly associated with engineered channels, that is, a relatively straight, wide, trapezoidal channel, with a uniform profile designed to convey all flows (baseflow, bankfull flow, and flood flow). The channel banks are often armored with rip-rap or gabions (concrete revetment in more urbanized areas) in an effort to maintain this engineered form, and grade control structures may be installed to maintain bed stability. This engineered approach invites long-term problems due to the negative feedback mechanisms inherent in all stream systems. These channels are generally devoid of habitat.

4.1.2 Geomorphic Approach

A geomorphic approach utilizing natural stability concepts is recommended for the restoration of unstable reaches along Quittapahilla Creek and its tributaries.. This approach is system-oriented and works with, rather than against, the natural processes that shape and maintain stream channels. Restoration efforts are focused on: restoring a stable, self-maintaining channel form; reestablishing the critical interactions between the stream and adjacent riparian areas; restoring the natural functions of floodplains; modifying channel and floodplain maintenance practices that are inconsistent with these objectives; and minimizing the effects of land use by relocating structures from high hazard areas, and adopting land use controls throughout the watershed that are based on landscape capabilities. This approach also recognizes that natural streams are composed of three distinct channels: a thalweg or low flow channel; a bankfull channel; and a floodplain, which conveys flows greater than bankfull. Finally, this approach emphasizes bio-engineered stream bank stabilization techniques that utilize natural materials (e.g., rootwads, logs, boulders, etc.) and live plantings.

4.1.3 Level of Intervention

When implementing channel restoration or stabilization measures the level of intervention required is dictated by the severity of the problem. At the lowest level of intervention, restoration may involve simply eliminating the impacting activity and allowing natural recovery to proceed. For example, streams impact by livestock grazing will often recovery naturally after grazing has been eliminating by streambank fencing.

At the opposite end of the intervention scale, extremely unstable conditions with a poor potential for natural recovery may require complete reconstruction of the stream channel to provide a stable channel pattern, profile, and cross-section and the utilization of bank stabilization techniques, and installation of flow diverting and grade control structures.

Figure 4.1 – Stream in agricultural watershed impacted by livestock grazing.

Figure 4.2 – Same stream after fencing installed to limit livestock access.

Figure 4.3 – Stream in a residential area where landowner mowed to top of stream banks

Figure 4.4 – Same stream two growing seasons after mowing practices were modified

Figure 4.5 – This braided channel has poor natural recovery potential and requires complete restoration and changes in riparian land use practices.

Figure 4.6 – This deeply incised channel has poor natural recovery potential and requires complete restoration and stormwater retrofitting to stabilize hydrologic regime.

Figure 4.7 – Stream reach with bank erosion and lateral stability problems.

Figure 4.8 – Same stream reach with problem corrected with localized stabilization that included installation of toe benches.

Figure 4.9 – This deeply incised and straightened channel required complete channel restoration to reestablish meander geometry and reconnect the stream and floodplain

4.1.4 Designing the Stable Channel Form

- Empirical Relationships

Early studies in fluvial geomorphology established that relationships exist between various stream characteristics (i.e., channel width and meander geometry, meander geometry and longitudinal profile) and that streams respond in a predictable manner to changes in one or more of these characteristics.

- Reference Reach Concept

In theory a stream that has adjusted its channel geometry to accommodate the range of flows and sediment load delivered to it by its watershed and has remained stable over time provides an excellent model for how we want our project reach to look and function. Because these characteristics can be measured in the field, the goal of the geomorphic approach to channel restoration is to approximate a range of appropriate stream channel features, utilizing data gathered from stable reference streams in similar geomorphologic and hydrologic settings.

4.1.5 Channel Stabilization Techniques

- Grade Control

Grade control will be provided by the construction of cross vanes, boulder drop structures, or boulder steps at appropriate locations along the restored reaches. Construction of these features is in no way similar to weirs or check dams utilized in a standard engineered channel. The features have very specific design criteria including site location, plan form, cross-section and profile.

- Stream Bank Stabilization and Flow Diverting Techniques

Selecting stream bank stabilization and flow diverting techniques that complement the restored stable channel form should emphasize stability, habitat and aesthetics. Techniques that utilize rootwad and boulder revetment, cross vanes, rock vanes, log-boulder J-Hooks, boulder-drop structures, and boulder step-pools, look natural and are especially effective at providing structural stability. The objective of installing flow diverting structures is to reduce the shear stress on the stream banks by slowing and diverting the flow away from the banks and into deep water on bends or the center of the channel in crossover reaches.

- Live Plant Material

These techniques are supplemented by a variety of other innovative approaches (e.g., soil fabric lifts; toe benches with sod or willow mats, fascines, brush mattresses, willow posts, and soil/fabric lifts). Using plant materials appropriate for the soil and hydrologic conditions and adapted to the regional weather extremes is key to the long-term success of the project. Local or regional suppliers of native plants will be the best source of materials.

4.1.6 Floodplain and Wetland Restoration

The restoration objectives for Quittapahilla Creek and its tributaries include floodplain and wetland restoration and creation where practical. To increase flood storage, provide water quality treatment of urban and agricultural runoff, and create wildlife habitat some floodplain areas would be excavated and/or expanded depending on landowner acceptance. Approaches could involve: 1) expansion and enhancement of wetlands in natural drainage ways in the floodplain where relic channels already support wetland conditions; 2) excavation of floodplain areas adjacent to restored stream reaches; 3) excavation of floodplain areas in conjunction with modifications to the upstream side of culverts to create shallow impoundments; 4) construction of berms perpendicular to and across the floodplain to create shallow impoundments; 5) lowering of floodplain elevations to encourage more frequent flooding of adjacent riparian areas.

Figures 4.10 and 4.11 – Unstable stream reach (top) and same reach immediately after stabilization with log/boulder step-pools and toe benches (bottom)

Figures 4.12 and 4.13 – Same Log/Boulder Step-Pools 2 and 7 years after installation

Figure 4.14 – Log/Boulder Step-Pools 2 months after installation

Figure 4.15 – Log/Boulder J-Hooks 1 month after installation

Figures 4.16 and 4.17 – Log/Boulder J-Hooks and footbridge (top) and boulder step-pools (bottom) two months after installation

Figure 4.18 – Cross Vane sill under baseflow conditions

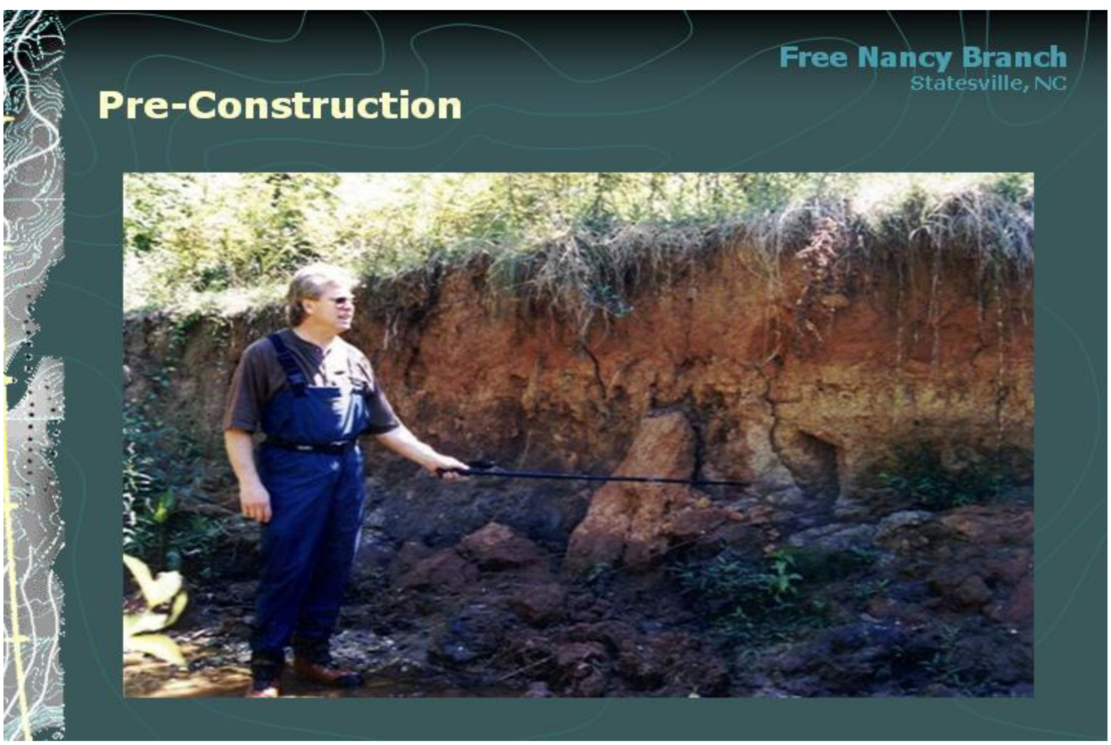
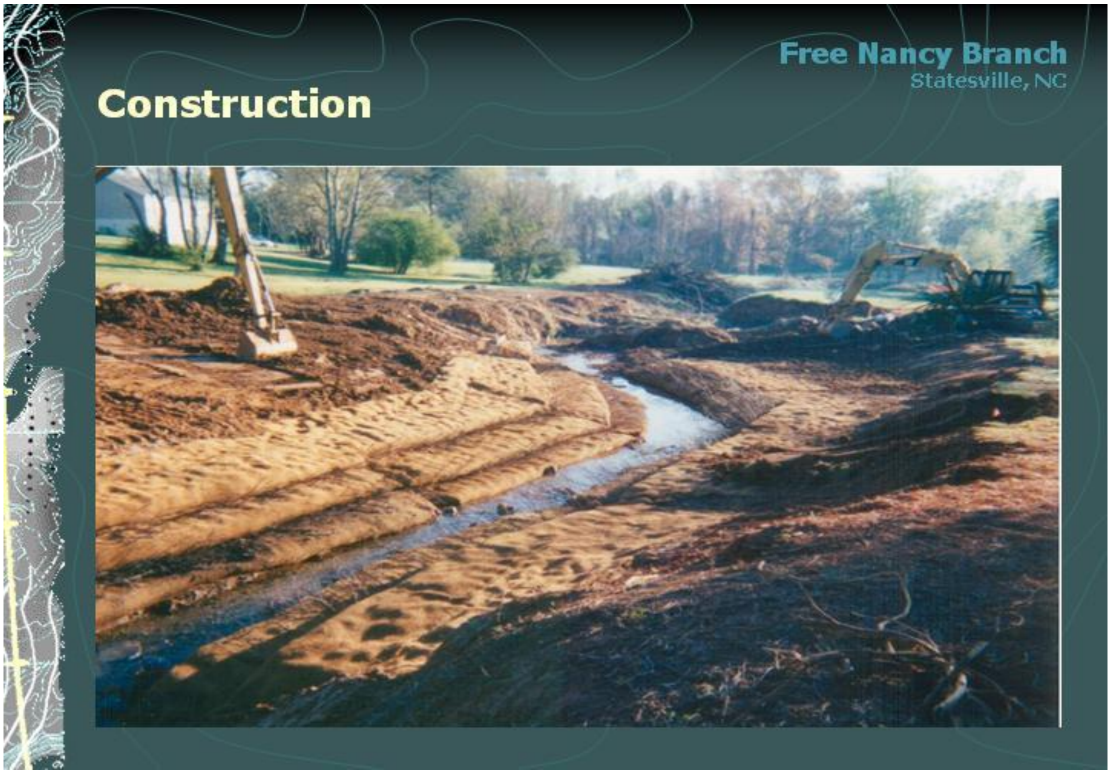


Figure 4.19 –Deeply incised and laterally unstable channel



Figures 4.20 and 4.21 – Same channel during construction (top) and four years after construction (bottom)

Figures 4.22 and 4.23 – Restoration of this stream included removal of a rubble land fill and the creation of 6 acres of wetlands. Top photograph taken one month after construction bottom photograph of restored Stadium Branch taken one year later

Figure 4.24 – Stadium Branch floodplain wetlands 1 year after construction

4.2 Evaluation Methods

As described in the Findings Report, the Generalized Watershed Loading Function (GWLF) model with a GIS software (ArcView) interface (AVGWLF) developed by Pennsylvania State University was utilized to analyze water quality during the assessment phase of this study. The model allows for estimates of sediment and nutrient loadings derived from stream bank erosion. Stream bank erosion is calculated using a “stream power” approach similar to that described by Dietrich et al. (1999) and Prosser et al. (2001).

As part of the assessment phase of the study estimates of sediment and nutrient loadings derived from stream bank erosion were calculated for each of the twenty one subwatersheds. It was assumed that the unstable reaches identified during the field reconnaissance and morphologic stream assessment account for 95% of the sediment and nutrient loadings derived from stream bank erosion, with the remaining 5% contributed by the stable reaches throughout all subwatersheds. This assumption formed the basis for evaluating the level of reductions in sediment and nutrient loadings that can be achieved with channel stabilization measures. The actual calculations of reductions were accomplished by determining the length of channel proposed for stabilization within given subwatershed. The percent reduction in this 95% pollutant loading was assumed to be equal to the length of restored channel as a percentage of the total length of channel within a given subwatershed.

For example, in the Brandywine Creek Subwatershed - 15 the total stream length is 28,050 feet. Approximately 15,180 feet (54% of the total channel length) was identified as unstable channel during the field reconnaissance. The total sediment load estimated to be derived from stream bank erosion for the Brandywine is 158,760 lbs per year. It is assumed that erosion along the unstable reaches account for 95% of that total sediment load or 150,822 lbs per year. Stabilizing the unstable reaches should reduce this loading by 54% or 81,443.9 lbs per year.

Table 4.28 shows the estimated pollutant loadings derived from stream bank erosion for each subwatershed. Table 4.29 shows the estimated reductions in pollutant loadings that will be achieved by implementing the recommended restoration and stabilization measures. Table 4.29 shows that nitrogen, phosphorus and sediment loadings that derive from stream bank erosion could be reduced by 42.8%, 42.8% and 43.9%, respectively by implementing the recommended stream stabilization measures. The subwatersheds that show the highest pollutant loading reductions include 1-Lower Main Stem, 12,-Middle Main Stem, 13-Lower Beck Creek, 14-Lower Snitz Creek, 16-Upper Quittapahilla Creek, 17-Upper Quittapahilla Creek, and 19-Upper Beck Creek.

SUBSHED	TOTAL N	95% N	TOTAL P	95% P	TOTAL S	95% S
1	8.2	7.8	3.5	3.3	158,760	150,822
2	1.1	1.05	0.4	0.38	22,712	21,576
3	13.2	12.5	5.7	5.4	263,057	249,904
4	9.7	9.2	4.2	4.0	193,379	183,710
5	2.2	2.1	1.1	1.05	45,864	43,571
6	4.4	4.2	2.0	1.9	87,318	82,952
7	0.4	0.38	0.2	0.19	7,497	7,122
8	1.5	1.4	0.7	0.67	32,414	30,793
9	0.2	0.19	0.0	0.0	2,646	2,514
10	0.7	0.67	0.2	0.19	14,112	13,406
11	3.3	3.1	1.3	1.2	63,945	60,748
12	26.5	25.2	11.7	11.1	527,877	501,483
13	8.2	7.8	3.3	3.1	151,704	144,118
14	20.1	19.1	8.4	8.0	386,757	367,419
15	12.3	11.7	5.5	5.2	246,960	234,612
16	6.4	6.1	2.9	2.76	125,685	119,400
17	2.0	1.9	0.9	0.86	41,234	39,172
18	4.9	4.7	2.2	2.1	96,800	91,960
19	0.4	0.38	0.2	0.19	8,600	8,170
20	1.1	1.05	0.4	0.38	20,286	19,272
21	2.6	2.5	1.1	1.05	52,479	49,855

Table 4.28 - Estimated pollutant loadings derived from stream bank erosion by subwatershed

SUBSHED	TOTAL STREAM LENGTH	UNSTABLE STREAM LENGTH	PERCENT REDUCTION	95% N (LBS/YR)	REDUCED LOADING N (LBS/YR)	95% P (LBS/YR)	REDUCED LOADING P (LBS/YR)	95% S (LBS/YR)	REDUCED LOADING S (LBS/YR)
1	46,580	32,720	0.70	7.8	2.34	3.3	0.99	150,822	45,247
2	13,200	3250	0.25	1.05	0.79	0.38	0.29	21,576	16,182
3	34,220	18,480	0.54	12.5	5.75	5.4	2.48	249,904	114,956
4	18,150	7930	0.44	9.2	5.15	4.0	2.24	183,710	102,878
5	11,880	2400	0.20	2.1	1.68	1.05	0.84	43,571	34,857
6	13,992	1320	0.09	4.2	3.78	1.9	1.71	82,952	74,657
7	12,210	1650	0.14	0.38	0.33	0.19	0.16	7,122	6,125
8	10,560	4455	0.42	1.4	0.81	0.67	0.39	30,793	17,860
9	3,630	150	0.04	0.19	0.18	0.0	0	2,514	2,413
10	7,920	660	0.08	0.67	0.62	0.19	0.17	13,406	12,334
11	19,470	8,250	0.42	3.1	1.80	1.2	0.70	60,748	35,234
12	29,550	18,225	0.62	25.2	9.58	11.1	4.22	501,483	190,564
13	26,400	18,880	0.72	7.8	2.18	3.1	0.87	144,118	40,353
14	36,300	24,080	0.66	19.1	6.49	8.0	2.72	367,419	124,923
15	20,130	9,095	0.45	11.7	6.44	5.2	2.86	234,612	129,037
16	4,650	4,650	1.0	6.1	0	2.76	0	119,400	0
17	4,200	3,200	0.76	1.9	0.46	0.86	0.21	39,172	9,401
18	25,080	11,920	0.48	4.7	2.44	2.1	1.09	91,960	47,819
19	16,500	10,470	0.63	0.38	0.14	0.19	0.07	8,170	3,023
20	15,840	7,010	0.44	1.05	0.59	0.38	0.21	19,272	10,792
21	10,560	5,680	0.54	2.5	1.15	1.05	0.48	49,855	22,933
TOTAL				123.0	52.7	53.0	22.7	2,372,724	1,041,586

Table 4.29 – Estimated pollutant loading reduction achieved by implementing stream stabilization measures

4.3 Proposed Restoration Measures

As noted previously, potential projects were identified from a list of subwatershed and main stem problem sites identified in Volume 1 of this report. These projects were selected for their potential for reducing loadings of sediment and other pollutants, correcting channel instability, and improving in-stream habitat problems. They include variety of project types at all levels of intervention. Low cost natural recovery type projects include stream bank fencing and livestock crossings and riparian buffer plantings. Stabilization type projects include bank grading and stabilization in urban areas, bank grading and stabilization with fencing in agricultural areas, and modifications to pond diversions. Full intervention restoration projects include stream restoration with reconstruction of channel geometry and installation of stabilization structures, dam and/or wall removal and channel restoration, channel restoration and creation of wetlands, modifications to culverts and/or bridge replacements. Some projects include unstable reaches that were identified as stormwater BMP sites. These sites present the Watershed Association with an either/or scenario. It is assumed that if the BMP is installed the restoration project would not go forward. However, if the BMP is not implemented than the channel restoration work would proceed.

Included in the project tables are recommended action items to be taken by the Watershed Association and their cooperating partners that are not reach specific projects, but critical to the overall restoration effort. Examples of these action items include working with the Royal Oaks Golf Course and Lebanon Country Club to modify riparian maintenance practices, working with the Millard Quarry to develop stormwater runoff control best management practices, and conducting feasibility studies of existing stormwater management facilities along the main stem Quittapahilla Creek in the City of Lebanon to evaluate the potential for retrofitting or upgrading water quality management functions.

The tables included in this section describe the restoration/stabilization projects recommended for implementation in the Quittapahilla Creek watershed and the accompanying figures show the location of the proposed projects. The projects listed here do not include the proposed SWM BMP facilities outlined in Section III. However, as indicated above, the overlapping BMP and restoration reaches are noted in the project tables. It should be noted that implementation of the proposed SWM BMPs will influence the long-term success of the channel restoration and stabilization projects along the upper main stem Quittapahilla Creek since the facilities are designed to control peak flows along these stream reaches.

Table 4.30 - Bachman Run Stream Restoration Projects

Project ID	Location	Length (feet)	Existing Problems	Proposed Solutions
1	East Fork Farm adjacent to Philhaven Hospital DS of Butler Rd	1320	Livestock grazing impacts; lack of buffer; unstable E4 channel with low eroding banks	Relocate existing fence a minimum of 15 feet to either side of stream and install two (2) livestock crossings.
2	East Fork Quarry	1980	Channelized, unstable C4 channel with high eroding banks; low baseflow conditions	Restore as stable C4 stream with constructed wetlands to treat agricultural runoff and augment baseflow.
3	Middle Fork Along East side of Rte 241	2640	Channel ditched and lacking buffer	Plant a minimum 35 foot riparian buffer.
4	West Fork UPS of Rte 241 and McCurdy Rd	500	Incised G4 channel with high eroding banks	Restore G4 reach as stable B4 stream.
5	West Fork UPS of Rte 241 and DS of McCurdy Rd	1810	Unstable B4 and C4 channels with high to moderately high eroding banks, aggraded sections with chute cutoff channels	Restore as stable B4 and C4 streams.
6	West Fork DS of Rte 241	700	Channel ditched and lacking buffer	Plant minimum 35 foot riparian buffer.
7	West Fork DS of Graystone Stables	1650	Unstable B4 and C4 channels with high to moderately high eroding banks, aggraded sections	Restore as stable B4 and C4 streams. Construct a wetland along this reach to treat agricultural runoff.
8	Main Stem Risser Farm	1320	Unstable B4/G4 channels with high to moderately high eroding banks, lacking buffer	Restore G4 reach as stable B4 stream. Plant a minimum 35 riparian buffer.
9	Main Stem Inman Property UPS of Rte 322	1650	Concrete walls and dam; unstable F4/C4 channels with high to mod-high eroding banks, aggraded, lateral and mid-channel bars in lower section.	Remove dam and walls; restore as a stable B4c stream.

Project ID	Location	Length (feet)	Existing Problems	Proposed Solutions
10	Main Stem Bachman Property DS of Rte 322	660	Livestock grazing impacts; lack of buffer; unstable C4 channel with moderately high eroding banks.	Grade and stabilize banks. Install fencing a minimum of 15 feet to either side of stream and install a livestock crossing.
11	Main Stem Horning Farm UPS of Fontana Rd	1320	Livestock grazing impacts; lack of buffer; unstable C4 channel with moderately high eroding banks.	Grade and stabilize banks. Install fencing a minimum of 15 feet to either side of stream and install a livestock crossing.
12	Main Stem Gary Horst Farm DS of Fontana Rd	1320	Livestock grazing impacts; concrete walls along one section; unstable C4 channel with moderately high eroding banks.	Restore as stable C4 stream; Install fencing a minimum of 15 feet to either side of stream and install a livestock crossing.
13	Main Stem Dr. Denalis Property DS of Private Drive	660	Unstable C4 channel with low to moderate eroding banks, lateral and mid-channel bars.	Restore as stable C4 stream and construct wetland in adjacent floodplain.
14	Main Stem Copenhaver Farm and Resnick Property UPS of Louser Rd	2376	Channelized C4 with stone walls along both banks.	Remove walls and restore as stable C4 stream and construct wetland in adjacent floodplain.
15	Main Stem Property DS of Louser Rd	1980	Unstable C4 channel with low to moderate eroding banks, lateral and mid-channel bars.	Restore as stable C4 stream and construct wetland in adjacent floodplain
16	Main Stem Wind Over Grove DS of Quittie Park Road	1320	Channelized and rip-rapped G4 in upper section; Channel split below ponds; unstable F4 and G4 along lower sections	Remove rip-rap from upper section; restore upper and lower sections as stable B4/B4c streams and construct wetland in adjacent floodplain.
	Total Length	23,206		

BACHMAN RUN MAP

Table 4.31 - Beck Creek Stream Restoration Projects

Project ID	Location	Length (feet)	Existing Problems	Proposed Solutions
1	UPS of Mine Rd	330	Incised G4 channel with high eroding banks migrating upstream through old breached dam	Remove dam and restore G4 reach as stable B2 stream.
2	Gretna Glen Camp UPS of lake	5000	Unstable B4, C4, F4, G4, F4 and C4 channel sections with high eroding banks along upper and middle sections, aggradation and bank erosion along lower section	Restore as stable B4 and C4 streams.
3	Gretna Glen Camp DS of lake	1980	Unstable G1 and C4 channel sections with very high eroding banks along upper section, aggradation, avulsions, and cut-off channels along middle and lower sections	Restore as stable B1/B2 and C4 streams.
4	Henry Farm DS of Camp	850	Livestock grazing impacts; lack of buffer; unstable E4 channel with low eroding banks.	Install fencing a minimum of 15 feet to either side of stream and install a livestock crossing.
5	Weaver Farm DS of Starner Rd and Ups of Rte 322	2310	Livestock grazing impacts; lack of buffer; unstable C4 channel with moderately high eroding banks.	Grade and stabilize banks; Install fencing a minimum of 15 feet to either side of stream and install two (2) livestock crossings.
6	Weaver Farm DS of Rte 322	1320	Livestock grazing impacts; lack of buffer; unstable E4 channel with low eroding banks.	Install fencing a minimum of 15 feet to either side of stream and install two (2) livestock crossings.
7	Property West of Spangler Rd UPS of Flutterby Farm	990	Rip-rapped C4 channel with high W/D ration and sedimentation	Remove rip-rap and restore as stable C4 stream.
8	Flutterby Farm And Radio Station Property	1860	Unstable C4 channel sections with moderately high eroding banks, lacking buffer in lawn area.	Restore as stable C4 stream. 35 foot riparian buffer along upper section. Create wetland system in old field area.

Project ID	Location	Length (feet)	Existing Problems	Proposed Solutions
9	Boyd Property UPS of Colebrook Rd	1300	Unstable E4 channel with moderate to moderately high eroding banks, lacking a buffer.	Restore as stable E4 stream. Plant a minimum 35 foot riparian buffer.
10	Eckenrode Property UPS of Colebrook Rd	700	Channelized, unstable C4 channel with moderate eroding banks, lacking a buffer, poorly constructed pond diversion.	Restore as stable C4 stream; plant a minimum 35 foot riparian buffer; modify pond diversion.
11	Bomberger Property Meadow Wood Farms DS of Colebrook Rd	1980	Livestock grazing impacts; unstable C4 channel with moderately high eroding banks; heavy sedimentation and aggradation; poorly constructed pond diversion	Restore as stable C4 stream; Install fencing a minimum of 15 feet to either side of stream; install a livestock crossing; modify pond diversion.
12	Property on Private Drive east of Forney Rd	500	Stream fenced but livestock watering access and crossing causing erosion and sedimentation problems.	Modify fencing configuration to reduce impacts.
13	Nolt Farm UPS of Royal Rd	600	Row crops planted to stream edge, no buffer.	Plant a minimum 35 foot riparian buffer
14	Nolt Farm UPS of Royal Rd	1650	Livestock grazing impacts; unstable C4 channel with moderate eroding banks and heavy sedimentation; bank revetment composed of concrete, cinder blocks and asphalt.	Remove concrete, cinder blocks and asphalt revetment; restore as stable C4 stream; install fencing a minimum of 15 feet to either side of stream; install a livestock crossing;
15	Royal Oaks Golf Course	3630	No buffers; tees and greens with retaining walls immediately adjacent to stream; heavy accumulations of grass clippings in channel; poorly constructed pond diversion.	Relocate channel sections away from existing tees and greens; create wetlands; plant a minimum 35 foot riparian buffer of grasses/low growing shrubs; modify maintenance practices to minimize impacts to water quality; modify pond diversion.
16	Lebanon Country Club	1650	No buffers; tees and greens immediately adjacent to stream; poorly constructed pond diversion.	Relocate channel sections away from existing tees and greens; plant a minimum 35 foot riparian buffer of grasses and low growing shrubs; modify pond diversion.

Project ID	Location	Length (feet)	Existing Problems	Proposed Solutions
17	Robert Copenhaver Farm DS of Reist Rd	1320	Stream fenced but crossing constructed with poor configuration such that fencing is ineffective; livestock grazing impacts; unstable C4 channel – banks completely trampled; heavy sedimentation and aggradation.	Install two (2) new crossings with modified configuration to eliminate impacts.
18	Ed Copenhaver Farm UPS of Bricker Rd	990	Stream fenced but livestock watering access and crossing causing erosion and sedimentation problems.	Install two (2) new crossings with modified configuration and materials to eliminate impacts.
19	Ron Copenhaver Farm DS of Bricker Rd	1590	Unstable C4 channels in upper and lower sections, low to moderate eroding banks, heavy sedimentation and aggradation; poorly designed and constructed fish habitat structures causing instability in middle E4 section	Remove fish habitat structures and restore as stable E4 throughout. Create large floodplain wetland system to treat agricultural and golf course runoff.
	Total Length	30,550		

BECK CREEK MAP

Table 4.32 - Brandywine Creek Stream Restoration Projects

Project ID	Location	Length (feet)	Existing Problems	Proposed Solutions
1	Stovers Dam to Mt Lebanon Cemetery	2970	Unstable F4, B4, E4, B4, and C4 channels with moderate to moderately high eroding banks, active headcuts along upper section, and aggradation along middle and lower sections. Minimal to no buffer.	Restore as stable B4c, B4, E4 and C4 streams; plant a minimum 35 foot riparian buffer.
2	Reinoeldville Tributary East of Miller St	825	Unstable G4 and B4 channels with high eroding banks along upper section, aggradation and bank erosion along middle and lower sections. Minimal to no buffer.	Restore as stable B4 streams; plant a minimum 15 foot riparian buffer along rear of yards and 35 feet along field.
3	Reinoeldville Tributary West of Miller St	1650	Unstable E4 with active head cut migrating upstream through B4 channel sections with moderately eroding banks throughout; minimal to no buffer along rear of yards.	Restore as stableE4 and B4 streams; plant a minimum 15 foot riparian buffer along rear of yards.
4	Main Stem Brandywine DS of 7th St	700	Unstable F4 channel with high eroding banks throughout and aggradation in lower section UPS of tunnel gate.	Construct a stormwater wetland basin at location of tunnel gate to provide peak attenuation and water quality management.
5	Sand Hill Tributary DS of Mechanic St	1650	Unstable C4 and E4 channels with low to moderately high eroding banks throughout, aggradation and bank erosion along middle and lower sections. Breached dam in middle section.	Restore as stableE4 and C4 streams Construct a stormwater wetland basin at location of old dam to provide peak attenuation and water quality management.
6	Sand Hill Tributary DS of Reinoehl St	600	Unstable G4 and E4 channels with an active headcut migrating upstream from pipe inlet at Municipal Waste Disposal Site.	Stabilize headcuts and restore as stable E4 and B4 streams

Project ID	Location	Length (feet)	Existing Problems	Proposed Solutions
7	Main Stem Brandywine UPS of Maple St	850	Piped section under open space area.	Open piped section and construct a stormwater wetland basin in open space area to provide peak attenuation and water quality management.
8	Main Stem Brandywine DS of Lehman St	700	Stream in grass and gabion flume.	Construct a stormwater wetland basin along flume and adjacent floodplain to provide peak attenuation and water quality management.
	Total Length	9.945		

BRANDYWINE CREEK MAP

Table 4.33 - Buckholder Run and Gingrich Run Stream Restoration Projects

Project ID	Location	Length (feet)	Existing Problems	Proposed Solutions
1	Buckholder Run Grubb Farm DS of Rte 322	1650	Channel ditched; incised with high eroding banks, unstable G4; no buffer	Restore channel as a stable E4 stream with adjacent floodplain wetlands.
1	Gingrich Run Funck Farm UPS of Rte 322	660	Livestock grazing impacts; lack of buffer; unstable C4 channel with high eroding banks	Grade and stabilize banks; Install fencing a minimum of 15 feet either side of stream and install livestock crossing
2	Gingrich Run UPS of Rte 322 Brough Property DS of Rte 322 and UPS of Meadow Lane	1485	Junk cars, trucks and buses stacked along top of banks and along floodplain; unstable C4 channel with high eroding banks, debris jams, mid channel bars	Acquire property; remove junk vehicles; restore as stable C4 stream and create wetland system in adjacent floodplain to treat agricultural runoff and wastewater discharges from Thousand Trails Campground.
3	Gingrich Run Smith Property DS of Meadow Lane	2310	Unstable C6 channel with moderately high eroding banks, debris jams, lateral and mid channel bars, heavy sedimentation	Restore as stable C6 stream and create wetlands in adjacent floodplain.
4	Gingrich Run Oberholtzer Farm	1650	Livestock grazing impacts; lack of buffer; unstable E6 and E4 channels with moderately high eroding banks	Grade and stabilize banks; Install fencing a minimum of 15 feet either side of stream and install two (2) livestock crossing
5	Gingrich Run MacDonald Farm DS of Long Meadow Rd and UPS of Killinger Creek	2400	Stream fenced but fencing ineffective; livestock grazing impacts; lack of buffer; unstable B4/B4c channels with moderately high eroding banks	Grade and stabilize banks; remove existing fencing and install higher quality fencing same location as old fencing and install two (2) livestock crossings
	Total Length	10,155		

Table 4.34 - Killinger Creek Stream Restoration Projects

Project ID	Location	Length (feet)	Existing Problems	Proposed Solutions
1	UPS of Rte 322 and Rte 117	700	Livestock grazing impacts; lack of buffer; unstable E4 channel with low eroding banks	Install fencing a minimum of 15 feet to either side of stream and install livestock crossing.
2	UPS of Rte 322 and DS of Rte 117	620	Livestock grazing impacts; lack of buffer; unstable C4 channel with high eroding banks	Grade and stabilize banks; Install fencing a minimum of 15 feet either side of stream and install livestock crossing
W-1	UPS of Brandt Road	1200	Agricultural Runoff, wastewater discharge, low baseflow	Acquire property and create wetlands system to treat agricultural runoff and wastewater discharges from S. Londonderry WWTP and augment baseflow
3	MacDonald Farm	2640	Livestock grazing impacts; lack of buffer; unstable C4 channel with moderately high eroding banks	Grade and stabilize banks; Install fencing a minimum of 15 feet and install two (2) livestock crossings. Create wetlands to treat agricultural runoff and wastewater discharges from Palm City WWTP
4	Buck Farm	2310	Livestock grazing impacts; lack of buffer; unstable C4 channel with moderately high eroding banks	Grade and stabilize banks; Install fencing a minimum of 15 feet either side of stream and install two (2) livestock crossings
5	Musser Farm	990	Livestock grazing impacts; lack of buffer; unstable C4 channel with moderately high eroding banks	Grade and stabilize banks; Install fencing a minimum of 15 feet either side of stream and install livestock crossing
6	Kreider Farm UPS of Killinger Rd.	1650	Livestock grazing impacts; lack of buffer; unstable C4 channel with moderately high eroding banks	Grade and stabilize banks; Install fencing a minimum of 15 feet either side of stream and install two (2) livestock crossings

Project ID	Location	Length (feet)	Existing Problems	Proposed Solutions
7	Kreider Farm DS of Killinger Rd.	330	Livestock grazing impacts; lack of buffer; unstable E4 channel with low eroding banks	Install fencing a minimum of 15 feet to either side of stream and install livestock crossing.
8	UPS of Rte 422	2970	Stream channel is concrete flume	Remove concrete flume; restore channel as stable E4 stream; plant riparian buffer
9	DS of Rte 422	2310	Stream channel is concrete flume	Remove concrete flume; restore channel as stable E4 stream and create wetland system in adjacent floodplain to provide water quality and habitat.
10	Quarry	990	Bank erosion and sedimentation along sections of tributary; unmanaged runoff from facility contributing to turbidity and sedimentation problems along main stem Quittapahilla Creek	Stabilize eroding banks on quarry property; work with Quarry Mgmt and PADEP to develop and implement water quality management plans for controlling runoff from facility
	Total Length	16,710		

Table 4.35 - Snitz Creek Stream Restoration Projects

Project ID	Location	Length (feet)	Existing Problems	Proposed Solutions
1	East Fork Anthracite Rd to Rte 419	1000	Short G4 section migrating upstream through stable B4. Reaches UPS and DS stable.	Restore G4 section as stable B4 stream; Excavate adjacent floodplain along Willow Rd to create intermittently flooded wetland system.
2	East Fork Rte 419 to Culvert St.	2310	Unstable B4, F4, C4, D4, F4, and B4 channels with high eroding banks along upper section, aggradation and bank erosion along middle and lower sections.	Restore as stable B4 and C4 streams. Modify opening at old roadbed in middle of project area to detain storm flows in floodplain UPS; excavate adjacent floodplain upstream of old roadbed to create intermittently flooded wetland system.
3	East Fork Culvert St to Cornwall Rd	1290	Unstable C4 and F4 channel sections with active headcuts and high eroding banks throughout and aggradation along lower section	Restore as stableC4 and B4c streams. Create wetlands in adjacent floodplain.
4	East Fork Cornwall Rd to confluence with main stem Snitz	1980	Stone walls along both banks upper section; unstable F4 channel in upper and middle sections with high eroding banks throughout; channelized B4/G4 in lower section	Remove stone walls and restore as stable B4c stream throughout.
5	Middle Fork Burd Coleman Village	300	Gullies eroding in headwaters along railroad	Repair gullies.
6	Middle Fork Alden St to Rte 419	400	Unstable C4 channel sections with low to moderately high eroding banks, lacking buffer in park area.	Restore as stable C4 stream. Plant a minimum 35 foot riparian buffer.
7	Middle Fork Cornwall Ctr near Old School	1650	Unstable C4 channel with debris jams, aggradation, and high eroding banks throughout.	Restore as stable C4 stream.

Project ID	Location	Length (feet)	Existing Problems	Proposed Solutions
8	Middle Fork Farm adjacent to North Cornwall Rd	2310	Livestock grazing impacts; unstable C4/F4 channel with moderately high to high eroding banks; heavy sedimentation and aggradation; dam in lower section	Remove dam; restore as stable C4 and B2 streams; install fencing a minimum of 15 feet to either side of stream; install two (2) livestock crossings
9	Middle Fork DS of North Cornwall Rd	1650	Unstable G4 channel with moderately high to high eroding banks, bank revetment composed of cinder blocks and rip-rap; lacking a buffer in lawn areas.	Remove cinder blocks and rip-rap revetment; restore as stable B4 stream. Plant a minimum 15 foot riparian buffer along yards.
10	Middle Fork and main stem Snitz confluence UPS of Rte 72	700	Unstable G4 channel with moderately high eroding banks, bank revetment composed of rip-rap; lacking a buffer in lawn area.	Remove rip-rap revetment; restore as stable B4 stream. Plant a minimum 15 foot riparian buffer along yard.
11	West Fork Burd Coleman Village	3960	Unstable B4, C4, and G4 channels with active headcuts, high eroding banks, heavy sedimentation and aggradation throughout; breached dam in upper section	Remove breached dam; restore as stable B4 and C4 streams.
12	West Fork UPS of Alden Lane	1980	Unstable C4 channel with moderate to moderately high eroding banks and heavy sedimentation throughout; gully erosion in adjacent fields; pond diversion.	Restore as stable C4 stream; repair gullies; evaluate impact of pond diversion. Evaluate potential for creating wetland system UPS of Alden Lane.
13	West Fork Quentin Riding Club DS of Rte 419	1320	Altered C4/B4c channel with no buffer	Restore as stable B4c; plant a minimum 15 foot riparian buffer.
14	West Fork Adjacent to Fairview Estates	850	Unstable F4 and B4 channels in lower section with high eroding banks and heavy sedimentation.	Restore as stable B4c and B4 stream.
15	West Fork Farm along Rte 72	1980	Stream ditched and lacking a buffer	Plant a minimum 35 foot riparian buffer along fields.

Project ID	Location	Length (feet)	Existing Problems	Proposed Solutions
16	Main Stem Snitz DS of Rte 72	1320	Unstable F4 channel with high to very high eroding banks and heavy sedimentation.	Restore as stable B4c stream.
17	Main Stem Snitz Royer Farm DS of Rocherty Rd	2310	Stream fenced and recovering from livestock impacts; heavy sedimentation observed.	Reevaluate recovery process to determine if intervention necessary.
18	Main Stem Snitz Property at rear of Quentin Cicle Shopping Center	1320	Unstable C4 channel with debris jams, moderate eroding banks, and heavy sedimentation; small dam on stream for diversion to off-line ponds.	Remove dam; restore as stable B2 stream with modified diversion to supply ponds.
19	Main Stem Snitz Spitler Farm UPS of Colebrook Rd	660	Unstable C4 channel with debris jams, moderate eroding banks, and heavy sedimentation;	Restore as stable C4 stream
20	Main Stem Snitz Zimmerman Property DS of Colebrook Rd	1500	Unstable E4 and C4 channels with debris jams, moderate to moderately high eroding banks, and heavy sedimentation	Restore as stable E4 and C4 streams.
21	Main Stem Snitz Creekside Subdivision UPS and DS of Creekside Drive	3000	Unstable C4 channels with high W/D ratio, moderate to moderately high eroding banks, heavy sedimentation, and aggradation throughout; no buffers.	Restore as stable C4 stream; plant a minimum 35 foot riparian buffer along both sides of stream through subdivision. Create wetlands in adjacent floodplain.
22	Main Stem Snitz Mill Farm DS of Creekside	600	Stream is fenced but ineffective; livestock grazing impacts; unstable C4 channels with high W/D ratio, moderate to moderately high eroding banks, and heavy sedimentation	Restore as stable C4 stream; install fencing with a modified configuration to limit access to stream. Create wetlands in adjacent floodplain.
23	Main Stem Snitz Property DS of Oak St	1980	Unstable C4 channels with moderate to moderately high eroding banks, and heavy sedimentation; poorly constructed pond diversions.	Restore as stable C4 stream; modify pond diversions.

Project ID	Location	Length (feet)	Existing Problems	Proposed Solutions
24	Main Stem Snitz Horse Farm UPS of Dairy Rd	1300	Livestock grazing impacts; unstable C4 channels with high W/D ratio, moderate to moderately high eroding banks, and heavy sedimentation	Restore as stable C4 stream; install fencing a minimum of 15 feet to either side of stream and install a livestock crossing.
	Total Length	37,670		

SNITZ MAP 1

SNITZ MAP 2

Table 4.36 - Upper Quittapahilla Creek Stream Restoration Projects

Project ID	Location	Length (feet)	Existing Problems	Proposed Solutions
1	Harold Wise Farm UPS of Birch Rd	1150	Livestock grazing impacts; unstable C4 channel with banks completely trampled, heavy sedimentation and aggradation throughout. No buffer.	Install fencing a minimum of 15 feet to either side of stream and install two (2) livestock crossings.
2	Quest, Inc UPS of Metro Drive	300	Minimal to no buffer.	Plant a minimum 15 riparian buffer along lawn area.
3	Lebanon Vocational Technology School Metro Drive to 8th Avenue	1450	Stable E4 channel with recently constructed wetland system on right and left floodplain areas.	Reconstruct wetland areas as a stormwater wetland basin to provide peak attenuation and water quality management.
4	Burger King and Yingst Exterminating UPS of Rte 422	300	Unstable F4 channel – moderately high eroding banks and aggradation throughout; No buffer.	Stabilize channel and establish 10 foot filter strip along top of both banks.
5	Rte 422 to 5th Avenue	1150	Unstable C4 and F4 channel sections – moderately high to high eroding banks, heavy sedimentation and aggradation throughout; minimal to no buffer	Restore as stableC4 and B4c streams Plant a minimum 20 foot riparian buffer.
6	5th Avenue to West Lincoln Avenue	2100	Unstable G4 and F4 channels with moderately high to high eroding banks, unconsolidated bed material and slag fill along left bank, heavy sedimentation and aggradation throughout, leachate seeping from left bank in several locations; concrete wall along right bank in upper section; minimal to no buffer	Remove unconsolidated material from bed and backfill with cobble/gravel mixture; remove slag fill from left bank to a depth of 15 feet and rebuild bank with clean soil; plant a minimum 20 foot riparian buffer along left bank. Construct a stormwater wetland basin immediately upstream of W. Lincoln Ave. to provide peak attenuation and water quality management.

Project ID	Location	Length (feet)	Existing Problems	Proposed Solutions
7	West Lincoln Avenue to 4th Street	1300	Recovering F4/C4 channel with a concrete wall in upper section and moderate to moderate high eroding banks, heavy sedimentation and lateral bar, in upper and middle sections; minimal to no buffer	Remove concrete walls; restore as stableC4 and B4c streams; plant a minimum 20 foot riparian buffer. Evaluate existing SWM facilities at Bambergers, Mini Storage, Electric Substation, and Lebanon County Transit Authority for retrofitting to maximize on-site water quality management
8	4th St to 8th St	2300	Channelized C4/F4 transitioning to concrete flume in upper section. Concrete flume in middle and lower sections.	Evaluate existing SWM facilities at Federal Credit Union, Lebanon Valley Farmers Bank, Edward H. Arnold Library, and YMCA for retrofitting to maximize on-site water quality management
9	12th and Rte 422	2150	Concrete flume throughout.	Evaluate existing SWM facility at Lebanon Paper Box and Mfg Co for retrofitting to maximize on-site water quality management
10	DS of Route 419 at State Drive	500	Agricultural and golf course runoff; low base flow along downstream reaches.	Remove gravel road and create wetland system in adjacent fields to treat agricultural runoff, augment baseflow and create habitat
	Total	13,000		

UPPER QUITTIE SUBSHED

Table 4.37 - Main Stem Quittapahilla Creek Stream Restoration Projects

Project ID	Location	Length (feet)	Existing Problems	Proposed Solutions
1	UPS of 22nd Street (Reach 1)	1450	Unstable C4/F4 channel with moderately high to high bank erosion, debris jams, aggradation (lateral and mid-channel bars); failing storm drain outfalls.	Alt 1 – Construct a stormwater wetland basin immediately upstream of 22nd St to provide peak attenuation and water quality management. Alt 2 – Remove debris jams, stabilize banks, narrow channel by constructing toe benches along channel margins, and install structures (e.g., log vanes, rock vanes, or log-boulder J-Hooks) to divert flow away from banks and create habitat. Both alternatives require repair of storm drain outfalls.
2	22nd St – Chestnut St (Reach 2)	850	Unstable C4 channel in lower section with moderate bank erosion. Backwater created by undersized bridge opening at Chestnut St causing aggradation (lateral and mid-channel bars).	Raise road and replace bridge with larger bridge span. Stabilize banks and install structures (e.g., log vanes, rock vanes, or log-boulder J-Hooks) to divert flow away from banks and create habitat.
3	Chestnut St – Reigle Auto Upholstery (Reach 3)	1640	Unstable C4 channel with moderate to moderately high bank erosion throughout.	Alt 1 – Construct a stormwater wetland basin to provide peak attenuation and water quality management. Alt 2 – Stabilize banks and install structures (e.g., log vanes, rock vanes, or log-boulder J-Hooks) to divert flow away from banks and create habitat.

Project ID	Location	Length (feet)	Existing Problems	Proposed Solutions
4	Snitz Creek – Elizabeth St (Reaches 7 and 8)	1475	Unstable C4 with incising streambed, mod high to high bank erosion in upper and lower sections, heavy sedimentation, aggradation, numerous tires along middle section	Install grade control structures at DS end of upper section and raise streambed, stabilize banks, narrow channel in middle section by constructing toe benches along channel margins, and install structures throughout (e.g., log vanes, rock vanes, or log-boulder J-Hooks) to divert flow away from banks and create habitat.
5	Elizabeth St – Bedrock Step UPS of Garfield St (Reach 9)	1400	Unstable C4 with moderately high to high bank erosion throughout, heavy sedimentation and aggradation; minimal to no buffer along both banks in middle and lower sections.	Stabilize banks, narrow channel by constructing toe benches along channel margins, and install structures (e.g., log vanes, rock vanes, or log-boulder J-Hooks) to divert flow away from banks and create habitat. Plant a minimum 20 foot buffer along the right bank and 35 feet along the left bank.
6	Garfield St – Bedrock Ledge (Reach 11)	1060	Unstable C4 with moderately high to high bank erosion throughout; minimal to no buffer along right bank in upper and middle sections and left bank in lower section.	Stabilize banks and install structures (e.g., log vanes, rock vanes, or log-boulder J-Hooks) to divert flow away from banks and create habitat. Plant a minimum 25 foot buffer along the right bank and 35 feet along the left bank.
7	Bedrock Ledge – UPS of Split channel at Mill St (Reach 12)	800	Localized bank erosion and minimal to no buffer along left bank in upper and middle sections.	Stabilize banks and plant a minimum 35 foot buffer along the left bank.

Project ID	Location	Length (feet)	Existing Problems	Proposed Solutions
8	UPS of Cleona Blvd – Drop at Footbridge (Reach 14)	1500	Unstable C4 with high bank erosion throughout; heavy sedimentation, aggradation; and minimal to no buffer along both banks	Stabilize banks, narrow channel by constructing toe benches along channel margins, and install structures (e.g., log vanes, rock vanes, or log-boulder J-Hooks) to divert flow away from banks and create habitat. Plant a minimum 20 foot buffer along the right bank and 35 feet along the left bank.
9	Drop at Footbridge – Beck Creek (Reach 15)	2150	Unstable C4 with moderate bank erosion upper and lower sections, debris jams, heavy sedimentation, aggradation; and minimal to no buffer along the right bank in the upper section both banks in the lower section.	Remove debris jams; stabilize banks, narrow channel by constructing toe benches along channel margins, and install structures (e.g., log vanes, rock vanes, or log-boulder J-Hooks) to divert flow away from banks and create habitat. Plant a minimum 35 buffer along both banks.
10	Beck Creek – Meander at Walnut St (Reaches 16 and 17)	1950	Unstable C4 with moderate to moderately high bank erosion; debris jams, heavy sedimentation, aggradation (lateral bars) throughout.	Remove debris jams; stabilize banks, narrow channel by constructing toe benches along channel margins, and install structures (e.g., log vanes, rock vanes, or log-boulder J-Hooks) to divert flow away from banks and create habitat.
11	Meander at Walnut St – Meander DS of Willow St (Reach 18)	1200	Unstable C4 in upper section with high bank and slope erosion; aggradation, cutoff channel, and failing storm drain outfalls. Minimal to no buffer along right bank in middle section.	Stabilize banks and slopes, narrow channel by constructing toe benches along channel margins, and install structures (e.g., log vanes, rock vanes, or log-boulder J-Hooks) to divert flow away from banks and create habitat; repair of storm drain outfalls; plant minimum 20 foot buffer along right bank.

Project ID	Location	Length (feet)	Existing Problems	Proposed Solutions
12	End of Bedrock-Boulder Meander DS of Spruce St – Old Dam in Quittie Park (Reach 21)	1600	Localized bank erosion.	Stabilize banks and install structures (e.g., log vanes, rock vanes, or log-boulder J-Hooks) to divert flow away from banks and create habitat.
13	Old Dam in Quittie Park – SD Channel along Bachman Rd (Reach 22)	1150	Unstable C4 with moderate to moderately high bank erosion in lower section; heavy sedimentation, aggradation (lateral and mid-channel bars) throughout.	Stabilize banks, narrow channel by constructing toe benches along channel margins, and install structures (e.g., log vanes, rock vanes, or log-boulder J-Hooks) to divert flow away from banks and create habitat.
14	UPS of Rte 934 – Meander at King St (Reach 23 lower section and 24)	2100	Unstable C4 moderately high to high bank erosion, heavy sedimentation, aggradation (lateral and mid-channel bars) throughout; minimal to no buffer along right bank.	Stabilize banks, narrow channel by constructing toe benches along channel margins, and install structures (e.g., log vanes, rock vanes, or log-boulder J-Hooks) to divert flow away from banks and create habitat; plant minimum 20 foot buffer along right bank.
15	Meander at King St – Split channel DS of Old Mill Dam (Reaches 25, 26 and upper 27)	3675	Unstable C4/F4 with high to very high bank erosion, heavy sedimentation, aggradation (lateral and mid-channel bars) throughout; minimal to no buffer along right bank in upper section.	Stabilize banks, narrow channel by constructing toe benches along channel margins, and install structures (e.g., log vanes, rock vanes, or log-boulder J-Hooks) to divert flow away from banks and create habitat; Construct single channel DS of old mill dam; plant minimum 35 foot buffer along right bank in upper section.

Project ID	Location	Length (feet)	Existing Problems	Proposed Solutions
16	Rte 422 – Concrete Flume DS of WWTP (Reach 28)	2150	Unstable C4 with low to moderate bank erosion, heavy sedimentation, aggradation (lateral and mid-channel bars) throughout.	Narrow channel by constructing toe benches along channel margins; install structures (e.g., log vanes, rock vanes, or log-boulder J-Hooks) to divert flow away from banks and create habitat.
17	Concrete Flumes DS of WWTP	2550 and 3275	Concrete flumes conveying Quittapahilla Creek are devoid of habitat and aquatic organisms. Secondary flume is deteriorated with broken sections of concrete and gaps allowing storm flow erode the soil base and causing further damage.	Remove both flumes and reconstruct a natural channel along this section of the creek. Construct a large floodplain wetland system to provide flood storage, water quality and habitat. At a minimum the damaged flume should be repaired.
18	End of Concrete Flume – Clear Spring Rd (Reach 29)	2000	Unstable C4 with moderately high to high bank erosion, debris jams, heavy sedimentation, aggradation (lateral and mid-channel bars) throughout.	Remove debris jams; stabilize banks, narrow channel by constructing toe benches along channel margins, and install structures (e.g., log vanes, rock vanes, or log-boulder J-Hooks) to divert flow away from banks and create habitat.
19	Clear Spring Rd – Syner Road (Reaches 30 and 31)	2700	Unstable C4 with moderate to moderately high bank erosion, numerous large debris jams, heavy sedimentation, aggradation (lateral and mid-channel bars) throughout.	Remove debris jams; stabilize banks, narrow channel by constructing toe benches along channel margins, and install structures (e.g., log vanes, rock vanes, or log-boulder J-Hooks) to divert flow away from banks and create habitat.
20	Syner Rd – Killinger Creek (Reaches 32 and 33)	2200	Unstable C4 with moderately high to high bank erosion, debris jams, heavy sedimentation, aggradation (lateral and mid-channel bars) throughout.	Remove debris jams; stabilize banks, narrow channel by constructing toe benches along channel margins, and install structures (e.g., log vanes, rock vanes, or log-boulder J-Hooks) to divert flow away from banks and create habitat.

Project ID	Location	Length (feet)	Existing Problems	Proposed Solutions
21	Killinger Creek – School Creek (Reaches 34 and 35)	3250	Unstable C4 with high to very high bank erosion, debris jams, heavy sedimentation, aggradation (lateral and mid-channel bars) throughout.	Remove debris jams; stabilize banks, narrow channel by constructing toe benches along channel margins, remove rip-rap in fishing club and install structures (e.g., log vanes or log-boulder J-Hooks) to divert flow away from banks and create habitat.
22	School Creek – Old Mill Race at Forge Farm (Reaches 36 - 38)	5300	Unstable B4c/C4 with high to very high bank erosion, heavy sedimentation, aggradation (lateral and mid-channel bars) throughout; islands immediately DS of Palmyra-Bellegrove Bridge.	Remove islands DS of Palmyra-Bellegrove Bridge; stabilize banks, narrow channel by constructing toe benches along channel margins, install structures (e.g., log vanes or log-boulder J-Hooks) to divert flow away from banks and create habitat.
23	Old Mill Race at Forge Farm – Unnamed Tributary (Reaches 39 and 40)	3210	Unstable C4 with moderate to moderately high bank erosion in upper section, heavy sedimentation, aggradation (lateral and mid-channel bars) throughout.	Stabilize banks, narrow channel by constructing toe benches along channel margins, and install structures (e.g., log vanes, rock vanes, or log-boulder J-Hooks) to divert flow away from banks and create habitat.
24	Unnamed Tributary – Syner Rd (Reaches 41 and 42)	2425	Unstable C4/B4c with high to very high bank erosion in upper section, heavy sedimentation, aggradation (lateral and mid-channel bars) throughout.	Stabilize banks, narrow channel by constructing toe benches along channel margins, and install structures (e.g., log vanes, rock vanes, or log-boulder J-Hooks) to divert flow away from banks and create habitat; plant trees along right floodplain.

Project ID	Location	Length (feet)	Existing Problems	Proposed Solutions
25	Syner Rd – Bedrock Section DS of Powerlines on Blauch Farm (Reaches 43 and 44)	2450	Unstable B4c/C4 with moderate to moderately high bank erosion in the lower section, debris jams, heavy sedimentation, aggradation (lateral and mid-channel bars) throughout; minimal to no buffer along right bank in middle and lower sections.	Remove debris jams; stabilize banks, narrow channel by constructing toe benches along channel margins, install structures (e.g., log vanes or log-boulder J-Hooks) to divert flow away from banks and create habitat; relocate fence a minimum of 25 feet from top of bank and plant buffer with trees and shrubs.
26	Bedrock Section DS of Powerlines on Blauch Farm – Riffle UPS of wetland swale that drains pond in left floodplain (Reaches 45 and 46)	2625	Unstable C4 with moderate to moderately high bank erosion, debris jams, heavy sedimentation, aggradation (lateral and mid-channel bars) throughout	Remove debris jams; stabilize banks, narrow channel by constructing toe benches along channel margins, install structures (e.g., log vanes or log-boulder J-Hooks) to divert flow away from banks and create habitat.
27	Riffle UPS of wetland swale that drains pond in left floodplain – Riffle at Beach Area (Reaches 47 and 48)	3150	Unstable C4 with moderate to moderately high bank erosion, numerous debris jams, heavy sedimentation, aggradation (lateral and mid-channel bars) throughout	Remove debris jams; stabilize banks, narrow channel by constructing toe benches along channel margins, install structures (e.g., log vanes or log-boulder J-Hooks) to divert flow away from banks and create habitat.
28	Riffle at Beach Area – Valley Glen Rd (Reaches 49 and 50)	1800	Unstable C4 with moderate bank erosion, numerous debris jams, heavy sedimentation, aggradation (lateral and mid-channel bars) throughout	Remove debris jams; stabilize banks, narrow channel by constructing toe benches, install structures (e.g., log vanes or log-boulder J-Hooks) to divert flow away from banks and create habitat.

Project ID	Location	Length (feet)	Existing Problems	Proposed Solutions
29	Valley Glen Rd – Swatara Creek (Reaches 51 and 52)	1950	Unstable C4/F4 with moderate to high bank erosion, numerous debris jams, heavy sedimentation, aggradation (lateral and mid-channel bars) throughout	Remove debris jams; stabilize banks, narrow channel by constructing toe benches along channel margins, install structures (e.g., log vanes or log-boulder J-Hooks) to divert flow away from banks and create habitat.
	Total Length	61,760		

Table 4.38 - Unnamed Tributary Stream Restoration Projects

Project ID	Location	Length (feet)	Existing Problems	Proposed Solutions
1	Struphar Farm DS of Rte 934	600	Livestock grazing impacts; lack of buffer; unstable F4 channel with moderately high to high eroding banks	Restore as stable B4c stream; install fencing a minimum of 15 feet to either side of stream and install a livestock crossing.
2	Bomgardner Farm DS of Rte 934	2970	Unstable C4 channel with debris jams, high eroding banks, aggradation and gully erosion in headwaters.	Restore as stable C4 stream; repair headwater gullies.
3	Wagner Property UPS of Palmyra Bellegrove Rd	300	Unstable F4/B4 with moderately eroding banks throughout; no buffer	Restore as stable B4c streams; plant a minimum 15 foot riparian buffer along both sides of stream across yard.
4	Gingrich Orchard UPS of Palmyra Bellegrove Rd	1155	Unstable F4, G4 and B4 channel sections with high eroding banks throughout and aggradation in lower section; junk scattered along upper section below pond; no buffer in upper section	Remove junk from upper section; restore as stable B4c and B4 streams; plant a minimum 15 foot riparian buffer along both sides of stream across yard below pond.
5	Meyer Farm DS of Palmyra Bellegrove Rd	4290	Stream fenced but livestock still grazing riparian area; livestock grazing impacts; unstable C4 and E4 channels with debris jams, low to moderately high eroding banks throughout, aggradation and bank erosion along middle and lower sections.	Restore as stableE4 and C4 streams. Reconfigure fencing and crossings to limit livestock access to stream and riparian area.
	Total Length	9,315		

UPPER QUIITTIE MS

LOWER QUITTIE MS

4.4 Preliminary Cost Estimates

Table 1.39 below provides preliminary cost estimates for design, permitting and construction of the storm water wetland facilities and stream restoration/stabilization projects presented in this study.

Design and Permitting costs include: consultant's professional fees for surveying, base map preparation, stream assessment, wetland delineation, biological monitoring, hydrology & hydraulic analysis, final design plans, construction documents, final design report, engineer's certification, permit application and agency meetings, and all expenses.

Construction Cost includes: consultant's professional fees for geotechnical studies, construction inspection for SWM ponds, construction management for stream restoration projects, as-built surveys, and all expenses; as well as the Construction Contractor's Costs including: mobilization, clearing & grubbing, construction stakeout, sediment control and dewatering, earthwork, SWM Pond control structures, rock for and installation of in-stream structures, erosion control matting, seeding & mulching, and landscaping.

Table 4.39 – Preliminary Cost Estimates for Quittapahilla Creek Stream Restoration Projects

Project ID	Type Project	Size Project	Design and Permitting Costs	Construction Costs
Bachman 1	Streambank Fencing	1320 feet	NA	$9,600.00
Bachman 2	Stream Restoration/Wetland Creation	1980 feet	$79,200.00	$148,500.00
Bachman 3	Wetland Creation	2640 feet	$35,000.00	$75,000.00
Bachman 4	Stream Restoration	500 feet	$25,000.00	$50,000.00
Bachman 5	Stream Restoration	1810 feet	$90,500.00	$181,000.00
Bachman 6	Riparian Buffer Planting	700 feet	NA	$2,250.00
Bachman 7	Stream Restoration/Wetland Creation+	1650 feet	$82,500.00	$165,000.00
Bachman 8	Stream Restoration	1320 feet	$66,000.00	$132,000.00
Bachman 9	Dam Removal Stream Restoration	1650 feet	$82,500.00	$206,250.00
Bachman 10	Bank Stabilization and Fencing	660 feet	$8,000.00	$30,000.00

Project ID	Type Project	Size Project	Design and Permitting Costs	Construction Costs
Bachman 11	Bank Stabilization and Fencing	1320 feet	$8,000.00	$67,600.00
Bachman 12	Stream Restoration And Fencing	1320 feet	$8,000.00	$67,600.00
Bachman 13	Stream Restoration/Wetland Creation	660 feet	$19,200.00	$45,000.00
Bachman 14	Stream Restoration/Wetland Creation	2376 feet	$40,000.00	$120,000.00
Bachman 15	Stream Restoration/Wetland Creation	1980 feet	$59,400.00	$99,000.00
Bachman 16	Stream Restoration/Wetland Creation	1320 feet	$60,500.00	$99,000.00
Subtotal		23,206 feet	$663,800.00	$1,497,800.00
Beck 1	Dam Removal Stream Restoration	330 feet	$24,750.00	$35,000.00
Beck 2	Stream Restoration	5000 feet	$200,000.00	$500,000.00
Beck 3	Stream Restoration	1980 feet	$99,000.00	$198,000.00
Beck 4	Streambank Fencing Livestock Crossings	850 feet	NA	$5,750.00
Beck 5	Bank Stabilization and Fencing	2310 feet	$15,500.00	$114,550.00
Beck 6	Streambank Fencing Livestock Crossings	1320 feet	NA	$9,600.00
Beck 7	Stream Restoration	990 feet	$49,500.00	$74,250.00
Beck 8	Stream Restoration/Wetland Creation	1860 feet	$60,000.00	$99,000.00
Beck 9	Stream Restoration	1300 feet	$39,000.00	$97,500.00
Beck 10	Stream Restoration and Modify Pond Diversion	700 feet	$21,000.00	$47,250.00
Beck 11	Stream Restoration, Fencing and Modify Pond Diversion	1980 feet	$59,400.00	$120,400.00
Beck 12	Streambank Fencing Livestock Crossings	500 feet	NA	$1,250.00

Project ID	Type Project	Size Project	Design and Permitting Costs	Construction Costs
Beck 13	Riparian Buffer Planting	600 feet	NA	$100.00
Beck 14	Stream Restoration, Fencing	1650 feet	$49,500.00	$92,250.00
Beck 15	Stream Relocation, Wetland Creation, Riparian Buffer and Modify Pond Diversion	3630 feet	$90,750.00	$203,166.00
Beck 16	Stream Relocation, Wetland Creation, Riparian Buffer and Modify Pond Diversion	1650 feet	$49,500.00	$97,800.00
Beck 17	Modify Livestock Crossings	1320 feet	NA	$3,000.00
Beck 18	Modify Livestock Crossings	990 feet	NA	$3,000.00
Beck 19	Stream Restoration/Wetland Creation	1590 feet	$47,700.00	$87,500.00
Subtotal		30,550 feet	$805,600.00	$1,789,366.00
Brandywine 1	Stream Restoration	2970 feet	$148,500.00	$306,600.00
Brandywine 2	Stream Restoration	825 feet	$42,500.00	$86,900.00
Brandywine 3	Stream Restoration	1650 feet	$49,500.00	$83,640.00
Brandywine 4	Stream Restoration or SWM Wetland	700 feet	$35,000.00	$75,000.00
Brandywine 5	Stream Restoration or SWM Wetland	1650 feet	$49,500.00	$83,640.00
Brandywine 6	Stream Restoration	600 feet	NA	$30,000.00
Brandywine 7	SWM Wetland	850 feet	See SWM BMP 8	See SWM BMP 8
Brandywine 8	SWM Wetland	700 feet	See SWM BMP 8	See SWM BMP 8
Subtotal		9,945 feet	$325,000.00	$665,780.00
Buckholder 1	Stream Restoration/Wetland Creation	1650 feet	$49,500.00	$87,800.00
Gingrich 1	Bank Stabilization and Fencing	660 feet	$8,000.00	$29,800.00

Project ID	Type Project	Size Project	Design and Permitting Costs	Construction Costs
Gingrich 2	Junk Vehicle Removal, Stream Restoration/Wetland Creation	1485 feet	$41,250.00	$95,000.00
Gingrich 3	Stream Restoration/Wetland Creation	2310	$99,000	$148,500.00
Gingrich 4	Bank Stabilization and Fencing	1650 feet	$8,000.00	$85,750.00
Gingrich 5	Bank Stabilization and Fencing	2400 feet	$10,000.00	$120,000.00
Subtotal		10,155 feet	$215,750.00	$566,850.00
Killinger 1	Streambank Fencing Livestock Crossings	700 feet	NA	$5,000.00
Killinger 2	Bank Stabilization and Fencing	620 feet	$8,000.00	$27,600.00
Killinger W-1	Wetland Creation	1200 feet	$35,000.00	$99,000.00
Killinger 3	Bank Stabilization and Fencing	2640 feet	$16,200.00	$132,000.00
Killinger 4	Bank Stabilization and Fencing	2310 feet	$15,000.00	$115,500.00
Killinger 5	Bank Stabilization and Fencing	990 feet	$8,000.00	$49,500.00
Killinger 6	Bank Stabilization and Fencing	1650 feet	$10,000.00	$83,750.00
Killinger 7	Streambank Fencing Livestock Crossings	330 feet	NA	$3,150.00
Killinger 8	Stream Restoration	2970	$145,500.00	$295,000.00
Killinger 9	Stream Restoration/Wetland Creation	2310 feet	$148,500.00	$299,000.00
Killinger 10	Stream Restoration Implement SWM for Quarry	990 feet	$250,000.00	$500,000.00
Subtotal		16,710 feet	$636,200.00	$1,609,500.00
Snitz 1	Stream Restoration/Wetland Creation	1000 feet	$35,000.00	$65,000.00
Snitz 2	Stream Restoration/Wetland Creation	2310 feet	$115,500.00	$231,000.00

Project ID	Type Project	Size Project	Design and Permitting Costs	Construction Costs
Snitz 3	Stream Restoration/Wetland Creation	1290 feet	$64,500.00	$129,000.00
Snitz 4	Stream Restoration	1980 feet	$99,000.00	$198,000.00
Snitz 5	Gully Repair	300 feet	$5,000.00	$15,000.00
Snitz 6	Stream Restoration	400 feet	$1,600.00	$25,000.00
Snitz 7	Stream Restoration	1650 feet	$82,500.00	$165,000.00
Snitz 8	Dam Removal, Stream Restoration and Fencing	2310 feet	$69,300.00	$173,250.00
Snitz 9	Stream Restoration	1650 feet	$49,500.00	$123,750.00
Snitz 10	Stream Restoration	700 feet	$21,000.00	$40,000.00
Snitz 11	Dam Removal, Stream Restoration	3960 feet	$118,500.00	$297,000.00
Snitz 12	Stream Restoration, and Gully Repair	1980 feet	$59,400.00	$148,500.00
Snitz 13	Stream Restoration	1320 feet	$39,600.00	$99,000.00
Snitz 14	Stream Restoration	850 feet	$42,500.00	$85,000.00
Snitz 15	Riparian Buffer Planting	1980 feet	NA	$6,400.00
Snitz 16	Stream Restoration	1320 feet	$66,000.00	$132,000.00
Snitz 17	Streambank Fencing	2310 feet	NA	$5,775.00
Snitz 18	Dam Removal, Stream Restoration, Modify Pond Diversion	1320 feet	$66,000.00	$132,000.00
Snitz 19	Stream Restoration	660 feet	$19,800.00	$33,000.00
Snitz 20	Stream Restoration	1500 feet	$60,000.00	$112,500.00
Snitz 21	Stream Restoration/Wetland Creation	3000 feet	$90,000.00	$150,000.00

Project ID	Type Project	Size Project	Design and Permitting Costs	Construction Costs
Snitz 22	Stream Restoration/Wetland Creation and Fencing	600 feet	$20,000.00	$56,500.00
Snitz 23	Stream Restoration, Modify Pond Diversion	1980 feet	$59,400.00	$99,000.00
Snitz 24	Stream Restoration and Fencing	1300 feet	$25,000.00	$65,000.00
Subtotal		37,670 feet	$1,209,100.00	$2,586,675.00
Un Tributary 1	Stream Restoration and Fencing	600 feet	$8,000.00	$30,000.00
Un Tributary 2	Stream Restoration Gully Repair	2970 feet	$89,100.00	$140,500.00
Un Tributary 3	Stream Restoration	300 feet	$8,000.00	$15,000.00
Un Tributary 4	Stream Restoration	1155 feet	$40,200.00	$57,750.00
Un Tributary 5	Stream Restoration and Fencing	4290 feet	$35,000.00	$204,250.00
Subtotal		9,315 feet	$180,300.00	$447,500.00
Upper Quitti 1	Streambank Fencing	1150 feet	NA	$8,750.00
Upper Quitti 2	Riparian Buffer Planting	300 feet	NA	$200.00
Upper Quitti 3	SWM Wetland	1450 feet	See BMP 5	See BMP 5
Upper Quitti 4	Bank Stabilization and Riparian Plantings	300 feet	NA	$5,000.00
Upper Quitti 5	Stream Restoration	1150 feet	$57,500.00	$115,000.00
Upper Quitti 6	Stream Restoration SWM Wetland	2100 feet	$105,000.00 BMP 4	$262,500.00 BMP 4
Upper Quitti 7	Stream Restoration Evaluate SWM Retrofits	1300 feet	$65,000.00	$130,000.00
Upper Quitti 8	Evaluate SWM Retrofits	2300 feet	$20,000.00	NA
Upper Quitti 9	Evaluate SWM Retrofits	6150 feet	$25,000.00	NA
Upper Quitt 10	Wetland Creation	1200 feet	$40,000.00	$85,000.00

Project ID	Type Project	Size Project	Design and Permitting Costs	Construction Costs
Subtotal		17,400 feet	$312,500.00	$606,450.00
MS Quittie 1	Stream Restoration or SWM BMP	1450 feet	$72,500.00	$145,000.00
MS Quittie 2	Stream Restoration and Bridge Replacement	850 feet	$42,500.00	$85,000.00
MS Quittie 3	Stream Restoration or SWM BMP	1640 feet	$32,000.00	$164,000.00
MS Quittie 4	Stream Restoration	1475 feet	$73,750.00	$147,500.00
MS Quittie 5	Stream Restoration	1400 feet	$70,000.00	$140,000.00
MS Quittie 6	Stream Restoration	1060 feet	$53,000.00	$106,000.00
MS Quittie 7	Localized Channel Stabilization and Riparian Buffer Plantings	800 feet	$8,000.00	$32,000.00
MS Quittie 8	Stream Restoration	1500 feet	$45,000.00	$75,000.00
MS Quittie 9	Stream Restoration	2150 feet	$64,500.00	$161,250.00
MS Quittie 10	Stream Restoration	1950 feet	$58,500.00	$146,250.00
MS Quittie 11	Stream Restoration and Storm Drain Repair	1200 feet	$60,000.00	$120,000.00
MS Quittie 12	Localized Channel Stabilization	1600 feet	$48,000.00	$120,000.00
MS Quittie 13	Stream Restoration	1150 feet	$39,500.00	$86,250.00
MS Quittie 14	Stream Restoration	2100 feet	$63,000.00	$157,500.00
MS Quittie 15	Stream Restoration	3675 feet	$147,000.00	$367,500.00
MS Quittie 16	Stream Restoration	2150 feet	$107,500.00	$215,000.00
MS Quittie 17	Concrete Flume Removal, Stream Restoration/Wetland Creation	2550 feet	$127,500.00	$637,500.00
MS Quittie 18	Stream Restoration	2000 feet	$100,000.00	$200,000.00

Project ID	Type Project	Size Project	Design and Permitting Costs	Construction Costs
MS Quittie 19	Stream Restoration	2700 feet	$135,000.00	$270,000.00
MS Quittie 20	Stream Restoration	2200 feet	$110,000.00	$220,000.00
MS Quittie 21	Stream Restoration	3250 feet	$130,000.00	$325,000.00
MS Quittie 22	Stream Restoration	5300 feet	$212,000.00	$530,000.00
MS Quittie 23	Stream Restoration	3210 feet	$128,400.00	$321,000.00
MS Quittie 24	Stream Restoration	2425 feet	$121,250.00	$242,500.00
MS Quittie 25	Stream Restoration	2450 feet	$122,500.00	$245,000.00
MS Quittie 26	Stream Restoration	2625 feet	$131,250.00	$262,500.00
MS Quittie 27	Stream Restoration	3150 feet	$126,000.00	$315,000.00
MS Quittie 28	Stream Restoration	1800 feet	$90,000.00	$180,000.00
MS Quittie 29	Stream Restoration	1950 feet	$97,500.00	$195,000.00
Subtotal		61,760 feet	$2,616,150.00	$6,211,750.00
Total Project		216,711 feet	$6,964,400.00	$15,981,671.00
Cost/Linear Foot			$32	$74

Table 4.39 (Cont'd) – Preliminary Cost Estimates for Quittapahilla Creek Stream Restoration Projects

4.5 Prioritization of Stream Restoration Measures

Two different methods were used to evaluate and prioritize the proposed restoration measures. The first method involved determining their potential to reduce pollutant loadings to the overall Quittapahilla Creek watershed. The second method involved determining their potential to reduce pollutant loadings within their respective subwatersheds.

Table 4.28 provides data by subwatersheds relative to pollutant loadings from stream channel erosion. This data allowed the subwatersheds to be ranked on the basis of their contribution to total pollutant loadings for the overall Quittapahilla Creek watershed. Table 4.40 below shows the subwatersheds ranked in descending order from greatest contribution to least contribution.

Ranking	Subwatershed #	Subwatershed Name
1	12	MS Quittapahilla Creek confluence Beck & Snitz Creeks
2	14	Lower Snitz Creek
3	3	MS Quittapahilla Creek confluence Killinger Creek
4	15	Brandywine Creek
5	4	Middle Killinger Creek
6	1	MS Mouth of Quittapahilla Creek
7	13	Lower Beck Creek
8	16	Middle Quittapahilla Creek
9	18	Upper Bachman Run
10	6	Upper Killinger Creek
11	11	Lower Bachman Run
12	21	East Fork Tributary to Snitz Creek
13	5	Upper Killinger Creek and Gingrich Run
14	17	Upper Quittapahilla Creek
15	8	Middle Gingrich Run
16	2	MS Lower Quittapahilla Creek
17	20	Upper Snitz Creek
18	10	Upper Gingrich Run
19	19	Upper Beck Creek
20	7	Buckholder Run
21	9	Tributary to Gingrich Run

Table 4.40 - Subwatersheds ranked in descending order from greatest contribution to least contribution to total pollutant loading from stream channel erosion.

Using the data from Table 4.29 allowed the subwatersheds to be ranked relative to their potential for reducing pollutant loadings to the overall Quittapahilla Creek watershed. Table 4.41 shows the ranking of subwatersheds from highest priority to lowest.

Ranking	Subwatershed #	Subwatershed Name
1	12	MS Quittapahilla Creek confluence Beck & Snitz Creeks
2	14	Lower Snitz Creek
3	3	MS Quittapahilla Creek confluence Killinger Creek
4	16	Middle Quittapahilla Creek
5	15	Brandywine Creek
5	1	MS Mouth of Quittapahilla Creek
6	13	Lower Beck Creek
7	4	Middle Killinger Creek
8	18	Upper Bachman Run
9	17	Upper Quittapahilla Creek
10	21	East Fork Tributary to Snitz Creek
11	11	Lower Bachman Run
12	8	Middle Gingrich Ru
13	5	Upper Killinger Creek and Gingrich Run
14	20	Upper Snitz Creek
15	6	Upper Killinger Creek
16	19	Upper Beck Creek
17	10	Upper Gingrich Run
18	7	Buckholder Run
19	2	MS Lower Quittapahilla Creek
20	9	Tributary to Gingrich Run

Table 4.41 Subwatersheds ranked relative to their potential for reducing pollutant loadings to the overall Quittapahilla Creek watershed. Ranking of subwatersheds is from highest priority to lowest.

Although restoration measures proposed for some subwatersheds may have a less significant role in reducing pollutant loadings for the overall Quittapahilla Creek watershed they can still have a significant influence on the overall water quality within their respective subwatersheds. For example, the ten subwatersheds that achieve the greatest reduction in nitrogen, phosphorus, and sediment loadings via implementation of the proposed restoration measures include Subwatersheds 16 – Upper Quittapahilla Creek; 17 – Upper Quittapahilla Creek; 13 – Lower Beck Creek; 1 – Lower Main Stem Quittapahilla Creek; 14 – Lower Snitz Creek; 19 – Upper Beck Creek; 12 – Main Stem Quittapahilla Creek near confluence with Beck and Snitz Creeks; 3 – Lower Main Stem Quittapahilla Creek at confluence with Killinger Creek; 21 – East Fork Tributary of Snitz Creek; and 18 – Upper Bachman Run. Implementation of the restoration measures proposed for these subwatersheds provides 100%, 76%, 72%, 70%, 66%, 63%, 62%, 54%, 54%, and 48% reductions in nutrient and sediment loadings, respectively.

With the exceptions of Subwatersheds 4, 15, and 19 the same subwatersheds rank in the top ten of both priority lists and Subwatersheds 4 and 15 are ranked within the top twelve of both lists. This suggests that significant benefits would be derived regardless of the specific ranking method utilized. Therefore it is strongly recommended that the all of the proposed restoration measures be implemented for at least the top twelve ranked subwatersheds to achieve the maximum water quality benefits obtainable from these types of measures.

Because of the total number of projects identified, no attempt was made to prioritize individual projects. However, preference should be given to implementing specific types of projects within the prioritized subwatersheds. Based on the number of miles of stream impacted and the cost-to-benefit ratio preference should be given to projects involving:
1) streambank fencing and installation of livestock crossings, 2) grading and stabilization of streambanks, 3) restoration of altered channels including removal of concrete channels, dams and/or walls, and 4) channel restoration that includes creation of wetlands.

Section 5 - Long-Term Management Strategies

5.1 Introduction

Local watershed management programs can preserve and protect the natural resources of the Quittapahilla Creek Watershed. At the core of the process are cooperative efforts among those who are affected by and those who will benefit the most from the resources within your watershed. This group includes all of you (i.e., public officials, private citizens, public interest groups, economic interests, and any other groups or individuals) who are interested in or might be affected by these programs. There are numerous tools available for managing and protecting Quittapahilla Creek and its tributaries from the adverse effects of human activities. In general terms, these tools can be classified as planning tools, regulatory tools, best management practices, and educational tools. In this section of the report we will be discussing the planning and regulatory tools applicable to the Quittapahilla Creek watershed.

5.2 Planning Tools

The Comprehensive Plan currently being prepared by Lebanon County in cooperation with the City of Lebanon and the surrounding boroughs is a document that assesses the current social, economic, and environmental conditions in the region, and proposes changes to the management of growth and development in order to meet specific goals. Draft outlines of the document indicate that a major theme of the Plan is the control of suburban sprawl and a move toward sustainable development. From an environmental perspective, the Plan promotes economic opportunity while protecting and restoring the natural environment upon which the community's well-being and quality of life depends. In relation to the protection of Quittapahilla Creek and its tributaries, the final Plan should identify as minimum the following objectives:

- Protected watersheds, wetlands, and streams resulting in reduced pollution runoff, soil erosion and flooding, and clean, high quality water to meet the domestic, economic and recreational needs of the community.

- Environmentally sensitive development, which respects natural areas and enhances the quality of the built environment.

In order to meet these objectives, the Plan should outline policies and action agendas for the future, which include:

5.3 Policies

- Using the information collected during this watershed assessment as a baseline, continue to monitor water quality and stream conditions to determine the effectiveness of regulations and recommend changes as needed.
- Promote the utilization of building methods that emphasize reducing the amount of impervious surface.
- Promote more environmentally sensitive and aesthetically pleasing stormwater management systems.

- Educate landowners and businesses about the benefits of best management practices for stormwater protection.
- Enforce floodplain regulations more effectively.
- Consider the adoption of guidelines and/or regulations to manage development in environmentally sensitive areas.
- Integrate natural areas such as streams and wetlands into the site design of development projects and ensure that these areas are protected during development.

5.4 Action Agenda

- Implement the urban stormwater best management practices and restoration projects identified in this restoration and management plan.
- Promote a system of vegetative buffers along streams to filter pollutants.
- Implement a countywide stormwater management program that incorporates best available technology for controlling the quality and quantity of stormwater runoff.
- Review and amend, as necessary, the erosion control ordinance.
- Develop an environmental checklist for ensuring compliance with existing regulations.
- Consider an environmental review procedure, which includes assessing the environmental effects of development proposals.
- Study existing environmental protection practices for effectiveness.

5.5 Regulatory Tools

5.5.1 Federal Regulations

The largest federal regulatory programs for stream protection evolved out of the Clean Water Act passed by Congress in 1972. The stated objective of this Act is *to restore and maintain the chemical, physical, and biological integrity of the nation's waters*. The Clean Water Act guarantees citizens the right to know about the quality of their water and participate in programs and systems designed to keep those waters healthy. Citizens can get involved and provide comments about proposed permits for a variety of activities that could potentially adversely impact resources in the Quittapahilla Creek watershed.

The Section 404 Program controls the placement of fill and dredge materials in waters of the United States. Waters of the U.S. include lakes, rivers, streams, natural ponds, and wetlands. Permits are required from the U.S. Army Corps of Engineers (USACOE) before any fill or dredge activities can occur within these areas. The USACOE and other federal review agencies consider adverse impacts to waters of the U.S. during the permit application review process.

The National Pollutant Discharge Elimination System (NPDES) Program requires industrial and municipal point-source dischargers to obtain a permit before releasing wastewater to surface waters. NPDES permits require identification of pollutants in wastewater and set limits on these pollutants. There are currently fourteen active NPDES permits in the Quittapahilla Creek watershed.

In 1990, Phase I of the U. S. Environmental Protection Agency storm water program was initiated by amending the Clean Water Act to target non-point pollution sources. Through the use of Phase I, NPDES permits, municipalities populated by 100,000 people or more were required to develop storm water management plans for controlling and treating urban runoff. The Phase I storm water permit requirements also applied to large construction activities (i.e., disturbing 5 acres of land or more), and various categories of industrial activities.

The Phase II storm water program expanded the NPDES permit requirements to smaller urban municipalities and towns outside of urban areas that have populations of 10,000 or more and a population density of 1,000 people per square mile. Under Phase II, Lebanon County and the City of Lebanon were subject to these storm water permit requirements.

5.5.2 State Regulations

Section 401 of the federal Clean Water Act mandated that states establish water quality standards for their surface waters. As part of this mandate, the states are also required to certify that certain activities do not cause a violation of the water quality standards. For example, damming a stream to construct a pond may violate the state's water quality standard for temperature. In Pennsylvania, the Department of Environmental Protection administers the Water Quality Certification program, as required by the federal Clean Water Act.

In addition, Pennsylvania has adopted its own regulations for the protection of its streams. These regulations are codified in Title 25 of the Pennsylvania Administrative Code with specific chapters and sections that outline the state's water quality certification requirements, storm water management regulations, erosion and sedimentation control, etc.

5.5.3 Current Local Stream Protection Regulations

While administration, permitting and enforcement authority for many of the federal and state programs have remained with the respective state and federal regulatory agencies, implementation of some programs has been delegated to local municipalities. For example, the USEPA granted the State of Pennsylvania authority to administer the NPDES storm water permit program. In addition, local municipalities, such as the City of Lebanon and Lebanon County are responsible for obtaining permits and developing their own storm water management plans for controlling and treating urban runoff within their jurisdictions.

Response at the local level to these state and federally mandated programs has been highly variable nationwide. Some municipalities have moved forward rapidly to develop and implement the required programs. Some smaller cities and towns have not had the resources to dedicate to these programs and therefore have not yet met their objectives.

Lebanon County, the City of Lebanon and the boroughs have been working to meet many of the state and federally mandated requirements. State and federal requirements notwithstanding, the public officials who manage these local programs recognize the critical importance that protecting the natural resources of the Quittapahilla Creek watershed plays in maintaining the quality of life and economic viability of their communities.

5.6 Recommended Policies and Programs

The following stream protection policies and programs are recommended for inclusion in the local effort to provide for the long-term protection of the natural resources of the Quittapahilla Creek watershed. These programs will also facilitate the restoration of currently degraded resources and overall water quality improvements.

5.6.1 Timber Harvest Permits and Best Management Practices

This would involve implementation and enforcement of state of the art practices for maintaining streams and adjacent hillslopes in optimum condition where future timber harvesting and road building activities are planned. All loggers must obtain permits for timber harvesting and road construction on public and private lands. Under this management scenario, they would be required, as a condition of their permit, to submit a formal Best Management Practices Plan prepared by a licensed Forester.

The recommendation presented herein is that any proposed timber harvest in the Quittapahilla Creek watershed, on public or private land, should comply with a BMP Plan that is based on the strictest interpretation of Best Management Practices for Timber Harvesting required by the Pennsylvania Department of Environmental Protection.

This BMP Plan should include information relative to: location, size, and type of harvest; and methods for harvesting and removing timber. The Plan should address: avoiding sensitive areas; maximum allowable road density; harvest size relative to watershed size; construction details for skid trails, landing areas, access roads, and stream crossings; storm water diversion and control; erosion control and stabilization of disturbed areas; and removal and reclamation of roads. Staff of the Lebanon Conservation District should review and approve the Plan and monitor active and recently closed harvest areas to ensure loggers are in compliance with the permit requirements and Best Management Practices Plan.

5.6.2 Land Management Plans and Best Management Practices

This would involve implementation of state of the art best management practices for maintaining the stream and adjacent riparian landscape in optimum condition. All participating landowners would work with the Natural Resource Conservation Service to develop and implement a Land Management Plan that includes best management practices for agricultural land uses. For example, best management practices for grazing land along streams would include: fencing to restrict livestock access; installation of wells and/or development of springs and seeps to provide alternative water sources for livestock; appropriately sited and constructed livestock and farm equipment stream crossings; rest-rotational grazing and light grazing on pasture units; and delineation of riparian areas as separate land use management units where grazing is restricted.

5.6.3 Conservation Easements

This would involve remunerating landowners for voluntarily restricting their activities in sensitive areas identified on their parcels. By accepting the remuneration the landowner agrees to establish a conservation easement for a specified time period (e.g. 25-50 years) but does not give up ownership of the land.

Although it may not be practical to acquire or set aside for preservation all land within the floodplain and stream corridor, it is possible to identify areas that are the most prone to flooding, susceptible to erosion, or provide the minimum land area necessary for channel and floodplain restoration projects.

5.6.4 Land Acquisition

All or a portion of the floodplain and stream corridor on a vacant or leased parcel is purchased by a government agency to be set aside and maintained as a part of an undisturbed watershed protection area or stream/floodplain corridor. This approach is especially applicable to parcels that have been identified for conversion to wetlands or stormwater management facilities.

5.6.5 Stream/Floodplain Corridor -Land Use Covenants

This would involve establishing protective covenants on new lots and parcels at the time of subdivision approval. These covenants would establish riparian buffers that include wetland and floodplain areas and require a minimum buffer width be maintained from the top of stream bank on either side of the channel. The covenants would require that the vegetation in the buffers be maintained in a natural and undisturbed condition.

The buffer would be established by metes and bounds description, shown on the plat and recorded in the land records. The covenants would be clearly outlined on the plat and would pass with the property from owner to owner in perpetuity.